ICOS Observation System

ICOS RI Annual Report 2019

Approved by ICOS General Assembly

27 May 2020 ICOS/GA11/2020/5a



Contents

Foreword from Director General	3
2019 Highlights of ICOS Research Infrastructure	4
Introduction	5
Director General and Head Office	5
Highlights	5
Administrative and financial management of ICOS ERIC and ICOS RI	5
Support for the operations and development of the RI	8
Strategic developments	9
Management of external cooperation	10
Management of ICOS ERIC participation in externally funded projects	11
Outreach and communication	14
The Green Team	16
ICOS Carbon Portal	17
Highlights	17
Data service development (Task 1)	17
Infrastructure support (Task 2)	21
Data management and elaborated products (Task 3)	21
Training and user support (Task 4)	23
Management (Task 5)	24
Atmosphere Thematic Centre (ATC)	28
Data collection and availability (Task 1)	28
Network coordination, training and development (Task 2)	29
Ecosystem Thematic Centre (ETC)	32
Highlights	32
Data collection and availability (Task 1)	32
Network coordination, training and development (Task 2)	33
Ocean Thematic Centre (OTC)	36
Highlights	36
Data collection and availability (Task 1)	36
Network coordination, training and development (Task 2)	37
Central Analytical Laboratories -Central Radiocarbon Laboratory (CAL-CRL)	40
Highlights	40
Radiocarbon analysis of bi-weekly integrated CO ₂ samples (Task 1)	40
Radiocarbon analysis of CO ₂ from flask samples (Task 2)	41
Production of integrated CO ₂ samplers (Task 3)	42
Interaction with station PIs (Task 4)	42



Activities and plan reported to the DG, RI Committee and General Assembly (Task 5)	42
Central Analytical Laboratories - Flask and Calibration Laboratory (CAL-FCL)	44
Highlights	44
Trace gas analysis (CO ₂ , CH ₄ , CO, N ₂ O, SF ₆ , H ₂) of flask samples (Task 1)	44
Analysis of supplement parameters (CO $_2$ stable isotopes and O $_2$ /N $_2$ ratios) (Task 2)	44
Production of real air high pressure standard gases (CO ₂ , CH ₄ , CO) (Task 3)	45
Calibration and re-calibration of standard gases (Task 4)	45
Organisation of and participation in international QC activities (Task 5)	45
Activities and plan reported to the DG, RI Com and General Assembly (Task 6)	45
Interaction with station PIs (Task 7)	46
Monitoring Station Assemblies (MSAs)	47
Atmosphere MSA	47
Ecosystem MSA	47
Ocean MSA	47
ICOS National Networks' Highlights	49
ICOS Belgium	49
ICOS Czech Republic	54
ICOS Denmark	57
ICOS Finland	58
ICOS France	61
ICOS Germany	62
ICOS Italy	66
ICOS Netherlands	68
ICOS Norway	70
ICOS Sweden	72
ICOS Switzerland	73
ICOS UK	77
Main ICOS internal meetings	78
Main ICOS National Network meetings	78
Main events organised or co-organised by ICOS	78
Main events attended by ICOS ERIC	79
Main Publications 2019	79
Other materials	92



Foreword from Director General

On November 21, 2019, the General Assembly of ICOS ERIC made an extremely important, perhaps historical decision: it approved the updated member and observer contributions to ICOS ERIC and with that secured the second financial five-year period, 2020–2024. When ICOS was founded in 2015, the members and observers committed themselves for a five-year period 2015–2019. The renewed commitment by all countries is a strong signal and very positive feedback on the achievements of the ICOS community. Being one of the first distributed research infrastructures, ICOS ERIC has been again facing the challenge to find a path into undiscovered land and setting up a process ensuring a smooth transition into the second five-year period.

We had high ambitions when kicking off this process already in 2017: the goal was a strategy-guided transition including a perspective how the work of ICOS should develop in the upcoming five years. Thus, we reflected on the impact of ICOS and developed from this an updated strategy. Out of this strategy a five-year action plan has been developed and presented to the General Assembly in spring 2019. Based on this action plan finally the financial requirements were defined and discussed broadly within the entire research infrastructure. This became an iterative process with a steep learning curve for all of us. It even required an extraordinary meeting of the General Assembly in September which paved the way for the final decision in November. Looking now back at this long and winding road I am definitely proud and grateful to the entire ICOS community that cooperated so well and made ICOS again a benchmark for the management of complex distributed research infrastructures.

We finished the first five-year period by the end of 2019 with a clear strategic vision of ICOS, a strong commitment of all participating countries and more countries joining (Spain has officially announced to join ICOS in 2020 during the COP 25 at Madrid), and approved work and financial plans for the upcoming years. The core activity in this first period was definitely the final implementation of the infrastructure that made all of us extremely busy. We have established a functioning research infrastructure that is now ready to deliver the urgently needed knowledge on greenhouse gases in Europe. The key stone was set last year with integrating the UK part into the Ocean Thematic Centre which will strengthen the Ocean community within ICOS. We are ready to support the European Green Deal with the stepwise generation of knowledge from standardised systematic observation via science and assessment towards political action. In order to transfer this knowledge better into the political arena ICOS has successfully worked toward becoming an observing international organisation in the United Nations Framework Convention on Climate Change (UNFCCC). This status, given to us during COP 25 at Madrid enables us to organise official side events and provide statements towards the parties.

ICOS has further developed its international cooperation. We are actively supporting global data integration activities in all domains and we are cooperating with international organisations such as World Meteorological Organisation (WMO) and Group on Earth Observation (GEO). Our connections to fellow research infrastructures in other regions of the world have been intensified. The vison of an integrated, global carbon and greenhouse gas observation system with ICOS as the European pillar of it is manifesting.

In the upcoming period, two activities might become strategically more important: now that we are delivering data the connection to the scientific community using these data has to be strengthened. Furthermore, we need to establish improved funding streams for the basic operations that will make us more resilient against the fads of academic funding. The basic observational ICOS data are essential information for our societies and cannot be switched on and off based on the success of proposals in heavily competitive calls.

Werner Kutsch Director General



2019 Highlights of ICOS Research Infrastructure

- In 2019, ICOS had 138 stations: 36 in the Atmosphere, 81 in the Ecosystem and 21 in the Ocean network. During 2019, a total of 18 new stations received the ICOS label. The station labelling is an integrated process for final implementation of ICOS standards and compliance check for the stations, and it was the main activity of National Networks and Thematic Centres.
- All ICOS main operational observational data products, from raw to near real time to final quality-controlled data products, are now produced and are flowing from Thematic Centres to Carbon Portal and are available to the users, that find and access the data in strongly increasing numbers.
- Successful testing of the ICOS flask sampler enables a continuous quality control for continuously measured greenhouse gas concentrations of of CO2, CH4, N2O as well as CO.
- Scientific highlight of ICOS community was the Drought-2018 initiative, which will
 result in a special issue with 14 papers in the Philosophical Transactions of the
 Royal Society B journal. By combining the Drought-2018 data with the expanding
 ICOS Level 2 and near real time datasets, ICOS now provides up-to-date and
 continuous data sets that also cover the pre-ICOS period.
- ICOS was accepted as an Observer to the United Nations Framework Convention on Climate Change (UNFCCC). The observer status allowed ICOS to host a side event in COP25 in Madrid.
- UK formally joined OTC in summer 2019. This brought in administrative experience, high level academic leadership, and strong technological expertise from NOC to OTC.
- The CO₂ Green report of the European Commission states that Europe needs a more comprehensive ground-based monitoring of greenhouse gases, and proposes ICOS as the ideal partner: "The operational nature of ICOS research infrastructure, together with its well-established governance, makes ICOS a solid partner to coordinate the inclusion of additional in-situ components with respect to the requirements of the MVS capacity."
- ICOS ERIC coordinated H2020 RINGO and ENVRIPLUS projects and the RI as a whole participated in several others. From these projects, a majority of resources went to Central Facilities and National Networks. ERIC also participated in the preparation of several project proposals, such as CoCO2 and Atmo Access.
- The General Assembly approved the ICOS ERIC financial plan for 2020-2024, after a lengthy and complicated planning and negotiation process, which was thus successfully concluded.



Introduction

ICOS ERIC has been established as a legal entity to coordinate the operations of ICOS RI, distribute information from ICOS RI to user communities and to establish integrated data and analysis from GHG observation systems. ICOS ERIC provides effective access to coherent and precise data to facilitate research into multi-scale analysis of GHG emissions, sinks and their driving forces by making available measurement protocols, long-term data and data products. The statutory seat of ICOS ERIC is in Helsinki, Finland. ICOS ERIC has governance bodies such as General Assembly (GA), Director General (DG), ICOS Research Infrastructure Committee (RI Com), Scientific Advisory Board (SAB), and Ethical Advisory Board (EAB).

ICOS ERIC General Assembly is the decision-making body of ICOS RI and acts as a high-level council for Member and Observer representatives. General Assembly discusses and approves strategic issues as well as any legal, governance of financial issues, approves the official ICOS stations into the network and location of the facilities.

Director General is responsible for implementing the decisions adopted by the General Assembly and is the legal representative of the ICOS ERIC. The Director General carries out the day-to-day management of the ICOS ERIC and is responsible for managing staff and activities of the Head Office and the Carbon Portal in accordance with the ICOS ERIC budget. The Head Office supports the work of all ICOS ERIC governance bodies and day-to-day operations.

Carbon Portal (CP) is the one stop shop for all ICOS data and is part of ICOS ERIC. It is led by the CP Director who is employed by the ICOS ERIC. All other personnel are employed by either Lund University in Sweden, the main host and location of the CP, or Wageningen University in The Netherlands.

Director General and Head Office

Highlights

- During COP25, Spain announced its plans to become a member in ICOS RI.
- ICOS was accepted as an Observer to the United Nations Framework Convention on Climate Change, UNFCCC. The Observer status allowed ICOS to host a side event in COP25 in Madrid.
- General Assembly decided on the Financial Plan for the next five-year period, 2020-2024, in which it decided to increase station-based contributions and common contributions towards the Head Office and the Carbon Portal for the entire five-year period.
- Drafting of the ICOS 5-year plan for 2020-2024 was continued with feedback from the GA. The final version is pending adjustments to economical constraints from member state contributions, and therefore the final acceptance was postponed.

Administrative and financial management of ICOS ERIC and ICOS RI

ICOS ERIC and ICOS RI is a complex and distributed research infrastructure with the number of Horizon 2020 projects, which continuously writing new project proposals. Therefore, a certain number of resources is required to ensure the quality of the results and to meet the annual deadlines and requests of the European Commission and the legislation of the host countries.



Human resource administration of ICOS ERIC

At the end of year 2019, ICOS ERIC employed altogether 17 persons either with contract valid indefinitely or with fixed-term contracts. The justified reasons for fix-term contracts have relied on the Horizon2020 projects funding and preparing the materials for the upcoming five-year period, 2020-2024.

The following personnel was employed by ICOS ERIC during the year, some part-time:

- Director General (Werner Kutsch)
- Director of Carbon Portal (Alex Vermeulen)
- Head of Unit I 'Administration' (Anne Malm)
- Head of Unit II 'Operations' (Elena Saltikoff, from 01 September 2019)
- Interim Head of Unit III 'Strategy & International Cooperation' (Emmanuel Salmon)
- Head of Unit IV 'Communications' (Katri Ahlgren)
- Scientific Integration and Liaison Officer, Unit II (Jouni Heiskanen)
- Senior Officer, Communications (ENVRI-FAIR), Unit IV (Magdalena Brus)
- Senior Officer, Data Analyst, Unit II (Ville Kasurinen)
- Operations Officer, Unit II (Evi-Carita Riikonen)
- Science Officer, Unit II (Janne-Markus Rintala)
- Operations & Networking Officer, Unit II (Syed Ashraful Alam)
- Officer (SEACRIFOG project), Unit III (Mylène Ndisi)
- Communications Officer, (RISCAPE project Jan-Apr 2019), Unit IV, (Enni Sahlman)
- Assistant, DG Unit (Inka Hellä)
- Assistant, Unit I (Shawnie Kruskopf)
- EU-project Administration Assistant, Unit I (Leysan Karimova)
- Communications Assistant, Unit IV (Mari Keski-Nisula)

In addition, Pirjo Kontkanen continued as a legal counsellor of ICOS ERIC, and Communication Assistant Zoe Harrison was hired as a temporary employee from Staffpoint at the end of year.

In 2019, the Employee Survey was conducted among the ICOS ERIC Staff by the company named 'Corporate Spirit' and it was selected in accordance with the procurement rules. The Carbon Portal staff visited ICOS ERIC HO in August 2019.

Head Office supports the professional training and development of its personnel. In 2019, two staff members completed EMMRI eMBA program (Executive Masters on Research Infrastructure Management) provided by the University of Milan-Bicocca; and a staff member continued UNITAR training for 'Core Diplomatic Training'. During the year, a staff member participated in 'Supervisor training' and 'Occupational Health and Security Manager Training' organised by the HY+ and Finnish Occupational Health Institute, respectively. Another staff member attended in 'Project Management Training for Researchers' organised by the University of Helsinki. Some other staff members participated in numerous seminaries and conferences.

Financial Management of ICOS ERIC

In 2019, the first five-year period for the funding from the Academy of Finland was reported. The oneyear funding from the Academy of Finland was received and thereafter, the funding period from the Academy is harmonised with the ICOS five-year period. ICOS ERIC submitted a proposal for 2020-2024 funding to the Academy in August 2019 and altogether 2.25 million euros was granted for the period of 2020-2024. In addition, the Finnish Meteorological Institute confirmed its commitment to pay 2.25 million euros to ICOS ERIC over the funding period 2020-2024, subject to funding granted by the Parliament of Finland annually.



The EU-project ENVRIplus, coordinated by ICOS ERIC, ended in July, 2019. ICOS ERIC is still coordinating EU-project RINGO. The management of the EU-projects has improved during the year, given the three periodic reports being submitted to the EU Commission. Two new EU-projects was funded from the beginning of the year, and the decision to participate in several proposal writing was made at the end of year.

The drafting process of Five-Year Action and Financial Plan for the next five-year period (2020-2024) was started and based on this process, the Annex II of the ICOS ERIC Statutes has started to update. The task descriptions of the ICOS RI's Finance Management and the ICOS ERIC's Human Resource Management were drafted for the Management Plan.

According to the decision made by the General Assembly held on 10.12.2015, the ICOS Financial Committee was formed in May 2016 to support the financial management of ICOS ERIC and ICOS RI. This five-member committee consists of either General Assembly delegates or nominated experts. In 2019, the Chair of the Committee Marc de Jong died unexpectedly and this was a huge lost for whole ICOS RI. The current members are: Sirpa Nummila (Chair), Salah Dib, Gelsomina Pappalardo, Johanna Spångberg and Michele Oleo. During the year 2019, the committee had one day-long face-to-face meeting in Amsterdam, and two virtual meetings. In 2019, a virtual common meeting was also organized with the RI Committee and the Financial Committee.

Support to the contract management, procurement and coordination of the service providers for the Head Office

The first invoice to Joint Research Centre (JRC) was sent after delivering the service. The Head Office has Azets as a service provider for accounting and payroll, ATEA for IT-services and -support, KPMG for Auditing and VAT-matters. In 2019, the UK officially joined to OTC after signing the agreement. Also, the agreements with some of the national Focal Points have signed, and this work will continue in 2020.

General Assembly

General Assembly had three face-to-face meetings in 2019. The two-day spring meeting of General Assembly was held in Paris, France, on 22 May 2019. RI Committee representatives as well as SAB Chair participated in the Information Day preceding the decisive meeting on 21 May. During the day, the Head Office representatives and Central Facility directors presented the status of the research infrastructure. The main focus of the day was on the 5-year action and financial plans. In the decisive meeting, e.g. the Annual Report 2018, strategically justified activities presented in the 5-year Action Plan were approved and ICOS Strategy finalised. The Second version of the 5-year Financial Plan, update on Financial Rules and ICOS Evaluation were discussed. Six new stations received the ICOS label in the meeting.

An extraordinary General Assembly meeting was held on 30 September in Amsterdam, The Netherlands. The General Assembly discussed the ICOS 5-year Financial Plan and reached an 'ad referendum' decision to increase the common contributions towards Head Office and Carbon Portal as well as the station-based contributions towards the Central Facilities. The autumn General Assembly was held in Helsinki, Finland on 21 November 2019. In the meeting Werner Kutsch was re-elected as a Director General, and Jean-Marie Flaud as the Chair of the General Assembly. The General Assembly confirmed the 'ad referendum' decision taken in the previous meeting on the changed common and station-based contributions and approved budgets, membership contributions and work plans for 2020. Twelve new stations received the ICOS label. Members for the ICOS Evaluation Committee were selected in the meeting.



Scientific Advisory Board and Ethical Advisory Board

ICOS Scientific Advisory Board (SAB) has been operational since 2016. For the term May 2016- May 2019, the members of ICOS of SAB were Anna Michalak (Chair), Beverly Law (Vice-Chair; until May 2019), James Butler, Marcus Reichstein and Rik Wanninkhof. To ensure continuity of SAB, a rotation system as follows was approved by the General Assembly 22 May 2019: one member has their term extended by one year (rotate off in 2020), one has their term extended by two years (rotate off in 2021), and two get reappointed to three-year terms. SAB members for the term May 2019-May 2020 are Anna Michalak (Chair), James Butler, Ankur Desai, Marcus Reichstein and Rik Wanninkhof.

SAB provided its third report to the General Assembly in spring 2019. The report gave an assessment on ICOS status, feedback and recommendations on further development of the ICOS Strategy. The SAB had a face-to-face meeting on 20 November 2019, where the strategy and the draft of the ICOS 5-Year Action Plan were discussed thoroughly.

The Ethical Advisory Board (EAB), nominated in November 2016, consists of three members for the first two-year term: Silvia Peppoloni, Meri Vannas and Per Sandin. EAB had no meeting in 2019.

Support for the operations and development of the RI

Coordination and support for the Central Facilities, RI Committee, MSAs, National Networks, and SAB

Developing the Management Plan and Updating Five-Year Plan were major topics for 2019, and involved all bodies of the RI. The Head Office facilitated this process by drafting the documents and acquiring input from GA, SAB, RI Com and National Networks, and by making this an iterative process to guarantee the whole RI buy-in for the topics elaborated in these documents. This included separate face-to-face meetings and teleconferences between all the actors.

Station labelling was another major activity concerning the whole RI. The Head Office supported the Central Facilities (CFs) in the process by communicating with the CFs and station PIs and steering the formal approval process. The Head Office also supported MSAs and Thematic Centres in identifying and solving issues that arise from the complexity of applying unified standards for heterogeneous station network.

RI Committee held two face-to-face meetings, on 26-28 February in Paris, France and on 24-26 September in Duebendorf, Switzerland. The specific focus in these meetings were the discussions on the ICOS vision and mission, long term strategy and 5-year planning. Updates and follow-up on station labelling process in the three domains is a regular topic in the meetings. Furthermore, RI Committee met virtually in monthly video-conferences. RI Committee participated in preparation for the General Assembly meetings, attended the discussion day event on 21 May 2019, as well as the SAB meeting on November 2019.

In 2019, members of RI Committee were:

- HO Jouni Heiskanen , substitute Katri Ahlgren
- CAL Ingeborg Levin, substitute Armin Jordan
- ETC Dario Papale, substitute Bert Gielen
- ATC Leonard Rivier, substitute Michel Ramonet
- CP Alex Vermeulen, substitute Harry Lankreijer
- OTC Richard Sanders (from September) Benjamin Pfeil (from June 2018), substitute Erik Sandquist
- MSA Atmosphere Huilin Chen, substitute Martin Steinbacher
- MSA Ecosystem Corinna Rebmann, substitute; Janne Rinne



• MSA Ocean, Thanos Gkritzalis, substitute Susan Hartman

ICOS ERIC supported financially the MSA activities and participated in all meetings organized in the three domains. The meetings are important events for following the progress of ICOS RI as well as scientific and technical developments in the ICOS scientific community.

Supporting the development of the RI

Concrete actions for the development of the RI were done in many levels. The Head Office supported Central Facilities in engaging and drafting project proposals. Several internal processes were either improved or drafted to answer specific cases, such as how to proceed when voluntary observation ship needs to be changed, how to proceed when new development need emerges in different parts of the RI. Information flows between ICOS bodies were improved e.g. related to sharing information on ICOS engagement with other networks.

Some development needs were identified, such as clear descriptions of processes related to managing different parts of the RI, or system for monitoring the performance of the RI. The Head Office started processing these issues. The most important strategic developments are being described in the next chapter.

Strategic developments

The strategy of ICOS was adopted by the General Assembly in November 2018. It establishes a vision up to the end of the 2020's and sets a perspective for ICOS RI associated with an ambitious five-year action plan (2020–2024). The strategy distinguishes four major areas of development.

ICOS Communities, operating and developing the RI

In 2019, ICOS has started an exercise of mapping of its users and stakeholders. This exercise was performed by a working group composed of representatives of the different components of ICOS RI. The first result was presented to the RICOM in December 2019. It shows a total of about 20 groups of organizations whose interest in and influence on ICOS has been estimated. The resulting map also allows to cluster these groups into 5 categories, that will serve as a base for the second phase of the exercise to be carried out in 2020. This will allow to better analyze some key-groups of users and stakeholders and develop the relevant strategies to increase their engagement in ICOS. This should also contribute to an increased use of ICOS data and services.

Developing a stable data infrastructure

This strategic area includes the road towards an observational network with improved coverage and density. A significant effort has been made in the five-year action plan to attract new countries in ICOS: a goal of five new countries by 2024 has been set. If the countries targeted in the RINGO project have all been thoroughly accompanied (training, support for national processes, presentations of ICOS and the benefits to join...), significant progress has been made in 2019 with Estonia and Spain. The new Estonian roadmap of research infrastructures was adopted in July 2019 and the national network of ICOS-EE found its way to the selected infrastructures. The question of its funding is still pending and should be decided in 2020. There are thus good hopes that Estonia could then join ICOS. The same applies to Spain that announced in December 2019 (at the side-event organized by ICOS at the COP25, see below) its official intention to join ICOS in 2020. The preparations of the necessary steps towards a formal application have started immediately.



Facilitating current and future science

ICOS is determined to further develop relevant methods for urban GHG measurement approaches, that are already applied as prototypes, the so-called city observatories. There is enormous interest by the European Commission that continues to encourage the development of a continental monitoring and verification support capacity for anthropogenic emissions. The support is currently provided through Horizon 2020 projects like VERIFY (see below) or CHE (where ICOS is not a partner as such but where many key individuals of ICOS are involved). It should be an important pillar of the next framework program for research Horizon Europe. As requested by the European Commission, ICOS also provided input for the internal reflection in relation to the preparation of Horizon Europe and the newly endorsed European Green Deal.

Management of external cooperation

Cooperation in the European landscape

ICOS ERIC actively cooperates with other European Research Infrastructures, both bilaterally and within several European frameworks. As the coordinator of the H2020 cluster project ENVRIPIUS, ICOS had a prominent role in bringing together the European research infrastructures of the environmental cluster into a strong community. This long-term work has made it possible for some partners to receive funding for the H2020 project ENVRI-FAIR, where the Carbon Portal and ICOS HO have an important role. The final event of ENVRIPIUS in Brussels in June 2019 received an excellent feedback from its more than hundred participants as well as from the representatives of the Research Infrastructure Unit of the Directorate General Research of the European Commission. At the end of 2019, DG Werner Kutsch was elected as the Deputy Chair of the Board of Environmental Research Infrastructures (BEERI).

The strategy of ICOS further encourages the search for innovative synergies between the European RIs, e.g. by promoting integrated scientific concepts, technical interoperability, co-location of measurement sites. The global frameworks of cooperation, for instance in the terrestrial ecosystem domain (see below GERI), also foster collaboration between the European actors, such as ICOS, eLTER and AnaEE. In 2020, it is envisaged to reinforce the contacts with the relevant infrastructures and work concretely on the development of common standards, protocols, and policies.

International collaboration

The explicit objective of ICOS in terms of international cooperation is to secure its position as the European pillar of an integrated, global carbon and greenhouse gas observation system. A first major step was achieved in 2019 with the successful application as an intergovernmental organization (IGO) observer to the United Nations Framework Conventions on Climate Change (UNFCCC). For the first time at the COP25 held in Madrid, ICOS had a seat in the negotiation rooms and was able to organize a side-event entitled "Standardized observations are the base of all climate science". It gathered experts from the main global actors: WMO, GCOS, NIES. On the occasion of this side-event, Spain announced its intention to join ICOS.

The discussions at the global level with partners in the field of terrestrial ecosystem research continued in 2019. After a promising meeting organized by the Chinese Academy of Sciences and its Chinese Ecosystem Research Network (CERN) in 2018, the workshop that was convened in Boulder by the American NEON allowed to further develop the concept of a Global Environmental Research Infrastructure (GERI). This concept was presented in Shanghai in December 2019 at the meeting of the Group of Senior Officials (GSO) on research infrastructures. It was positively received and the members



of GERI were asked to further elaborate the internal governance of the consortium, in order to make it a strong distributed infrastructure to be added on the list of research infrastructures of global interest.

ICOS has also reinforced its cooperation with WMO and its IG³IS Initiative. After a well-attended workshop on urban GHG measurement organized by ICOS-Finland in September 2019, there are plans to continue the work on harmonization of standards and development of a solid concept for city observatories during another workshop in 2020.

The Group on Earth Observations (GEO) is an important framework of cooperation for ICOS. The activities of the GEO Carbon and Greenhouse Gas Initiative (GEO-C) were limited in 2019, due to changes in strategic priorities at the GEO Secretariat. ICOS nevertheless further contributes actively to the definition of a new role for in situ observations in the GEO framework, together with other research infrastructures like ILTER. ICOS participated in the GEO Week in Australia, which also included this year a ministerial segment. The ENVRI booth at the exhibition part of the event was an excellent place to explain the role of research infrastructures in Europe. ICOS was also presented as an example of a distributed environmental RI in the "Data for our planet: Increasing the use and value of global information infrastructures to support resilient cities, disaster risk reduction and infectious diseases" side-event organized by CODATA.

Management of ICOS ERIC participation in externally funded projects

Horizon 2020 Projects and new Proposals

Director General and Head Office coordinate the ICOS ERIC and ICOS RI participation in different proposals and EU funded projects. ICOS ERIC seeks funding opportunities that support the development of the ICOS RI and enhances European and global integration of greenhouse gas observations. ICOS ERIC follows the guidelines on ICOS participation in proposals, approved by the General Assembly.

ENVRIplus

ICOS ERIC successfully coordinated the ENVRIplus, a Horizon 2020 project bringing together Environmental and Earth System Research Infrastructures, projects and networks with technical specialist partners to create a more coherent, interdisciplinary and interoperable cluster of Environmental Research Infrastructures across Europe. In 2019, a high-level event in Brussels for disseminating the project's results was organized by ICOS ERIC. The event brought together over 110 attendees from different backgrounds (scientists, as well as decision makers, funders and journalists). The event was considered a huge success. In 2019, ICOS also continued the work on the joint ENVRI strategy and the sustainability of the project developments. Another important achievement, finalized by the HO in 2019, was the delivery of White paper on further integration of RIs in the environmental field including recommendations on co-locating research sites at national and international level.

The originally planned end of the project was extended from April 2019 until July 2019. After the end of the project, ICOS ERIC coordinated the development and submission of the final ENVRIPLUS project report that was successfully delivered to EC later that year. ICOS as well developed a comprehensive overview of the most important outcomes of ENVRIPLUS - this report was very widely communicated and appreciated especially by the European Commission.

ENVRI-FAIR



Environmental Research Infrastructures build FAIR services for research, innovation and society, is a Horizon 2020 funded project. Its goal is that at the end of this project, all participating Research Infrastructures have built a set of FAIR data services. Such development will enhance the efficiency and productivity of researchers, support innovation and connect the ENVRI Cluster to the EOSC. ICOS ERIC, as a leader of three WPs and participant to altogether 9 WPs (out of 11), has a prominent role in the project. ICOS ERIC coordinates the work on Communications, ENVRI community building and the visibility, work on common requirements and testbed for (meta)data services, community standards and cataloguing, and last but not least, work on the training and capacity building of the RI staff.

RINGO (Readiness of ICOS for Necessities of Integrated Global Observations)

RINGO is a Horizon 2020 project coordinated by the Director General of ICOS ERIC. The progress of the project was disseminated in the Annual Meeting held in March 2019 at Southampton, UK, with approximately 70 participants.

As part of the project, updated versions of the data, dissemination, and risk management plans were completed. These contributed to the compilation of the wider RI-management plan which also includes the definitions of Key Performance Indicators (KPI) used for monitoring the RI's operability and are linked to the KIIs (Key Impact Indicators) used for measuring the societal impact of ICOS-RI, defined earlier in the ICOS Impact Assessment Report. These management achievements during the RINGO project have paved the way for the upcoming evaluation, in which the RI's performance is assessed against internal management, present and future KPIs, internal integration, user engagement and integration to European and global GHG information systems.

The process of writing the ICOS Stakeholder handbook was completed in 2019. The printed version was distributed within the RI and the key stakeholders who are closely associated with it. Due to a great demand, an improved 2nd edition was compiled and published online almost immediately after the publishing of the printed version in May 2019 (ISBN 978-952-94-1950-0).

During the Summer 2019, several summer schools and training events were organized by the RINGO members as part of routine standard operations. RINGO funding facilitated participation from ICOS 'candidate countries' as well. Head Office RINGO coordination team provided support to Spain during the summer that led Spain to announce its commitment to join ICOS in COP25.

In October-November 2019, the coordination team organized teleconferences with each task leader. These discussions were used to explore: 1) different options for successful completion of delayed deliverables; 2) future prospects for improving the readiness of ICOS with those results gained from successfully completed deliverables and to determine if these are mature enough to be implemented as part of routine operations and what it would cost; and 3) where future funding could be applied to continue the necessary development work of the RI.

During the last quarter of 2019, the location and time for the next annual meeting were announced. Detailed instruction was provided for the 2nd Periodic Report.

RISCAPE (European Research Infrastructures in the International Landscape)

The year 2019 observed the achievement of the RISCAPE project, concluded by a final event organized in Brussels in December 2019. RISCAPE aimed at describing the landscape of Research Infrastructures outside of Europe. ICOS was the leader of WP3 dedicated to environmental sciences. More than 30 interviews were carried out with international RIs and the main findings in terms of scope, funding, data policy were analysed in a domain report. All domains included in RISCAPE were then aggregated in a final report which was presented at the abovementioned event.



SEACRIFOG (Supporting EU-African Cooperation on Research Infrastructures for Food Security and Greenhouse Gas Observations)

The goal of the SEACRIFOG project is to promote the EU-Africa cooperation dialogue at different levels (policy, science, society) on the following themes: land use change, climate-smart agriculture, carbon cycle and greenhouse gases observations, in order to support mitigation and adaptation to climate change. The overall aim of SEACRIFOG is to build an integrative network for long-term and sustainable cooperation among African and European environmental research infrastructures. The project's outcomes would include the production of an assessment of the situation in Africa on the above-mentioned topics as well as a roadmap on the way forward. The individual sub-aims of SEACRIFOG are tackled in eight work packages. ICOS is leading WP7: High-level policy liaison and funding concept; and participating in WP3: Developing a common research agenda to promote Carbon, GHG and aerosols observation in Africa to fill gaps in a global observation system; and WP5: Interoperability of RIs, Access, Data Sharing.

Significant progress was achieved in all work packages. In the past operational year, the project achievements are: the SEACRIFOG collaborative tool developed alongside essential variables and results of refined emission factors at several events. These were presented in the concept of a pan-African system for the observation of GHGs. In particular, ICOS was represented at the biennial meeting of the High-Level Dialogue Platform on Science, Technology and Innovation between the European Union and the African Union. SEACRIFOG was prominently displayed and cited in the final conclusions of the meeting as an example of a successful project supporting the cooperation between both continents. SEACRIFOG, now in its final stage of implementation, is working on harnessing the most of dialogue with different levels of its network through the 1st meeting of the SEACRIFOG Dialogue Platform. The platform has an agenda to foster concrete output and impact with regards to EU-AU cooperation in the aforementioned themes and in a future system for GHG observation in Africa. Long term and sustainable cooperation between African and European environmental research infrastructure through an integrated and multidisciplinary solution is desirable.

VERIFY (Verifying Greenhouse Gas Emissions)

The aim of the H2020 VERIFY project is to develop a system to estimate greenhouse gas (GHG) emissions and support countries in their reporting tasks to the UN Framework Convention on Climate Change. The emissions are estimated based on land, ocean and atmospheric observations. The project focuses on the three major greenhouse gases responsible for global warming: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). The primary aim of VERIFY is to develop scientifically robust methods to assess the accuracy and potential biases in national inventories reported by the parties through an independent pre-operational framework. The main concept is to provide observation-based estimates of anthropogenic and natural GHG emissions and sinks as well as associated uncertainties. The proposed approach is based on the integration of atmospheric measurements, improved emission inventories, ecosystem data, and satellite observations, and on an understanding of processes controlling GHG fluxes (ecosystem models, GHG emission models).

The main role of ICOS in the project is to contribute to the communication on the project and the dissemination of its results. This was for example the case at the COP25 in Madrid where ICOS had a poster, together with ECMWF and other partners, presenting the new architecture envisaged by the European Commission of a Monitoring and Verification Support (MVS) Capacity. This endeavour will be built on the results of VERIFY and the other related H2020 project CHE.



EOSC-Pilot (Project supporting the first phase in the development of the European Open Science Cloud)

ICOS HO and Carbon Portal participated EOSC-pilot project supporting the development of the European Open Science Cloud (EOSC). ERFI (Environmental Radiative Forcing Integration) science demonstrator focused on the interoperability between Observational and Climate Modelling Environmental Research Infrastructures. Scientific use case was implemented in a cloud platform provided by EGI and to run land surface model using climate model outputs from IS-ENES data infrastructure.

Danubius PP (International Centre for Advanced Studies on River-Sea Systems)

ICOS ERIC is a beneficiary in DANUBIUS-PP, which is a preparatory phase project to build DANUBIUS-RI (International Centre for Advanced Studies on River-Sea Systems). As an established infrastructure, ICOS provides advice at many levels of the project. The work done in DANUBIUS on the engagement of stakeholders is also relevant for ICOS.

E-SHAPE (EuroGEO Showcases: Applications Powered by Europe)

E-SHAPE showcases are operational services in the field of Earth observation research in Europe coordinated by ARMINES, which is this regional GEO initiative aims to improve user uptake of Earth Observation data in the Europe. E-SHAPE includes 27 cloud-based pilot applications under 7 thematic areas to address societal challenges, foster entrepreneurship and support sustainable development, in alignment to the three main priorities of GEO, namely the Sustainable Development Goals (SDGs), the Paris Agreement and Sendai Framework.

ICOS HO is coordinating the Global Carbon and Greenhouse Gas Emissions (GCGE) pilot within the Climate Showcase. GCGE pilot in Climate show case is linked to scientific partners from atmospheric, terrestrial and ocean domains that will deliver the methodology used in Climate Show Case Services and demonstrations. Show case will produce remote sensing based estimates on terrestrial sources and sinks of carbon (FMI), the use of Near-Real-Time (NRT) flux data from ICOS measurement network (University of Helsinki), estimates of terrestrial carbon fluxes derived from data-driven machinery called FluxCOM (Max Planck Institute, CMCC), and maps regarding CO₂ emissions from ocean (University of Bergen and University of Exeter).

Outreach and communication

ICOS can considerably increase its impact to the society of ICOS and its data through outreach and communication. During the year, the Head Office made significant efforts towards that end. The FTE's in the Communications team varied between 150 and 230 during the autumn, as a result of a 50% study leave of one employee.

Biennial ICOS Science Conference

The preparations for the 4th Science Conference started on the second half of the year. The conference is to be held in September 2020 in the Netherlands, and organised together with ICOS Netherlands. A venue in the city of Utrecht was chosen and contracts with the University of Utrecht, the local organiser, were made. Moreover, the programme committee was selected and started its work. Once the general themes of the conference were decided upon, the website was opened and external communications started.



External outreach and networking

In 2019, the Head Office continued to promote ICOS mission and its services to a wide range of stakeholders. For that end, ICOS Head Office attended to few major international conferences and events, including participating on a joint ENVRI booth in the UN XVI GEO Plenary in Australia and in the EGU in Austria. ICOS also participated in AGU, having a joint session together with United States Carbon Cycle Science Program.

ICOS ERIC maintains a communications network for the communication officers of the Environmental RIs. The aim is to share the knowledge and best practices as well as news. ICOS was also part of a similar network within other RI clusters.

In Finland, ICOS ERIC organised a Fridays-for-Future climate change event together with ICOS Finland and the Finnish Meteorological Institute. The event, organised for the first time, was instantly fully booked with 100 about 15-20-year-old youngsters participating. The programme consisted of short scientific speeches and of a meet and greet session with scientists.

ICOS materials, presence in the web, media and social media

When it comes to gaining a share of voice in media and the social media, ICOS competes with hundreds of other, often larger organisations. We can be better heard and seen, if all ICOS units look similar and share same messaging. Thus, the ICOS RI visual image was updated with new unified colour palette for all Central Facilities, National Networks and Head Office. The update also included new PowerPoint and Word templates, business cards and other visual material.

In spring 2019, we also started a project to join the currently two separate ICOS Carbon Portal and Head Office websites. The project was unfortunately not finished by the end of the year as was originally planned: lack of resources in the Communications team delayed it until 2020.

ICOS' day-to-day external communication activities include production and dissemination of a wide range of engaging content such as news on the website and to the external newsletter. ICOS ERIC published 22 pieces of news on its website in 2019 (24 in 2018).

The single most important printed publication was the ICOS Handbook 2018. The Handbook is being used by community members to check processes, and by prospective member countries to communicate about ICOS, as well as by close stakeholder groups to convey messages of ICOS e.g. for funding agencies. About 600 copies of the book were sent; to all Principal Investigators of the statins, to ICOS partner institutes, funders and other cooperation organisations.

In social media, ICOS focuses its efforts on Twitter, Instagram, YouTube and LinkedIn. During 2019, our presence on Twitter, YouTube and LinkedIn has continued to grow. The number of Twitter followers increased by 47%, and LinkedIn group by 5% compared to 2018. The number of Instagram followers has decreased slighly, by 9%, largely due to the fact that ICOScapes campaign has finished. Videos published on ICOS YouTube channel have been viewed 8116 times altogether in August 2017-April 2020. Additionally, ICOS was mentioned at least 201 times in traditional media outlets in 2019, for example, in relation to the station labelling.

ICOScapes photo campaign

During 2019, ICOS continued to utilise the pictures and videos taken during the photo campaign ICOScapes that visited 12 stations in 12 countries during 2017-2018. The goal of the campaign is to gain visibility for greenhouse gas measurements and climate change within the general audience.



ICOS continued to gain visibility through the ICOScapes cooperation with the famous photographer Konsta Punkka. He has sometimes posted ICOS related posts or comments on his account, and by association, ICOS has gained hundreds of thousands of views and dozens of comments.

The physical ICOScapes photo exhibition containing 24 large pictures with respective station and climate change information was held in two locations in France for eight weeks in March-April, and for two weeks in Germany in summer. It continued to travel in Germany, being exhibited for another 8 weeks in two different locations in Germany. Materials from ICOScapes were also shown e.g. in ICOS Belgian Science Conference, ICRI conference, ESFRI meeting, and in the GEO Week 2019, where they received positive comments.

Internal RI communication

The Head Office regularly support internal communication activities across the ICOS RI. To enhance timely communication across the RI, the HO continued to publish a monthly community newsletter. It shares news from the National Networks, Central Facilities as well as from the Head Office. The HO also continued with the good cooperation with the RI Communications Network in order to align messaging and to share information and best practices.

The Green Team

ICOS ERIC established a Green Team in the beginning of 2019. The objective is two-fold: to have a critical reflection on the activities of ICOS ERIC in terms of environmental footprint and to contribute to the global combat against climate change. In January 2019, ICOS signed the Climate Neutral Now pledge, which is an initiative launched in the framework of UNFCCC. The goal is to mobilize individuals and organizations who commit themselves to monitor, reduce, and offset their greenhouse gas emissions. This ICOS decided to do for the emissions related to the home-work-home commuting and the business travels of all employees of ICOS ERIC (HO and Director of CP).

The principles for monitoring were decided upon, a routine reporting of individual emissions was implemented and at the end of 2019, the total GHG emissions was calculated. It amounted to 106 tonnes of CO₂. This figure will serve as the baseline for the reduction targets of ICOS ERIC in 2020, and the corresponding emissions were offset on the United Nations Carbon Offset Platform.



ICOS Carbon Portal

Highlights

- All ICOS main operational observational data products, from raw to near real time to final quality-controlled data products, are now produced and are flowing from Thematic Centres to Carbon Portal and are available to the users, that find and access the data in strongly increasing numbers.
- Large steps have been made in the implementation of the dynamic exchange of metadata between the Thematic Centres and the Carbon Portal in the framework of the data lifecycle working group, enabling the further compliance of ICOS to the FAIR principles.
- The development of virtual research environments through Jupyter notebook services was received with enthusiasm by the scientific community and has been used extensively already in projects like RINGO and EUROCOM and now also has found interesting applications in educational applications.
- The drought 2018 initiative proved to be a very successful enterprise where the support from the ICOS facilities enabled great science that will result in a large number of papers that build on ICOS data, while at the same time contributing to making available a unique set of historical pre-ICOS observational CO2 data on 48 atmospheric stations and 52 ecosystem stations with some data going back to as far as 1971 and updated up to the end of 2018.

Data service development (Task 1)

Emphasis of the development of the services has been on stability, user friendliness and performance of the services.

During the year 2019 a sharp increase in the data flow into and out of the Carbon Portal could be witnessed. The increase of ingested data objects leads to some performance issues with the SparQL queries in certain conditions. This performance issue is a well-known limitation of semantic web technology. It took a considerable effort to investigate the problem and to identify and implement as solution, but by the end of 2019 we had designed and implemented a solid and long-term solution to the problem that allows us to execute all queries within several tens of ms even for the increase prognosed in number of data objects for the next ten years.

All services have been in 2019 on line for more than 99.9% of the time. The only short hiccups we experienced were due to interruption in the services from the trusted repositories at PDC and CSC. After an initial period of testing of the new http B2STAGE interface to B2SAFE we had to stop in summer 2019 the streaming of data objects to B2SAFE due to increasing and unacceptable response times of the service. This issue has been resolved only in February 2020. In this period, we still could make use of the B2SAFE repository at PDC, through gridFTP, next to the local copy at Carbon Portal and the backups of this at our local backup, off campus.

In 2019 we also moved all remaining services, except for the Jupyter services, from the fsicos1 server to the new fsicos2 server. This required first an improved orchestration of the complex automatic launch of all services and monitoring of the running services in their confined virtual machines. At the moment we have over 20 different services running that need to start up in the correct order together with their dependencies on file system, data base connections and communication channels between the services. In principle all services could be run on different servers of a cluster if needed. The fsicos1 server is now 5 years old and should not be used any more for mission critical services and will only be



used for the anonymous Jupyter notebooks and footprint calculations with a short lifetime and no persistent data requirements.

Basic search through the portal app has been improved by taking in the received user feedback. We added online help for all elements of the portal app and changed the order of the search facets to match better the user expectations. Due to the increased performance of the SparQL queries we now also live update the search results based on the selected time filters and once available in the metadata also can live update search results based on a spatial data selection. Many improvements, large and small, have been applied to the portal app to improve the user experience, ease of access to the data and previews and the search work flow.



In spring 2019 we introduced the Dashboard app, that can be included in any website to advertise ICOS (at this moment only) atmosphere data for example in national network, university of newspaper websites. Through the Dashboard users can see the Near Real Time concentration at a station and link through to a graph of that data that includes both Level 2 and near real time data for that station.

In the framework of the ENVRIFAIR project ICOS participated in an assessment of the FAIRness of the ICOS data system. Although ICOS was identified as being fairly FAIR already, some areas have been identified that could be improved, especially with regards to the interoperability with the other environmental Research Infrastructures. As many of these are either more or less developed and follow different community standards some harmonization is required that

Figure 1 The Dashboard app

will take several iterations and years. Carbon Portal has already included many small changes in the metadata system and the services that prepare for these changes and that increased the FAIRness of the data portal and will enable to accommodate the necessary translation to the different controlled vocabularies of the different communities.

A huge step in the further integration of metadata across the RI was taken by setting up the mechanisms to sync the metadata between Carbon Portal and the Thematic Centers with relation to contributors, instruments and stations, replacing the preliminary and simplified setup chosen in 2015. OTC has chosen to follow the semantic web approach from Carbon Portal and uses the metadata editor mechanism and SparQL query language to update the metadata. ATC is pushing at a regular basis a copy of the most current metadata to Carbon Portal and ETC provides a service that can be queried by Carbon Portal to retrieve the most current metadata. Carbon Portal then detects all changes in metadata and implements these changes in the version-able RDF triple store to reflect the current state including the time information. Thanks to this approach the metadata can always be represented dynamically as a function of time, so that for example for the acquisition and submission time of a dataset the list of contributors for that station can be retrieved together with the list of curators from the TC, as well as the instruments, their status, the software versions used for processing etc.



Use of the Carbon Portal website

Use of the CP website is analysed using Google Analytics. Also, all services have on their pages the code to enable to track the use. Next to this we of course also track the downloads and previews of all data objects. Download statistics are registered for each individual data object and per access, so that we can report statistics by time and country of the downloader for any aspect of the metadata of the data objects, like for example station, domain, country, data level, etc or any combination of this.

Table 1 General overview of statistics and downloads for the whole year of 2019. Please note that new versions of data releases are counted as only one instance, older versions are not counted and do not normally pop up in search results (but can still be accessed through links from the current version or are shown when the advanced option "Show deprecated objects" is selected).

Total nr of unique visitors		20 418	
Pageviews			90 917
Average session duration		2:53	
New sessions			59.12%
Data objects stored			
All end 2018->end 2019 incl. depr.	63 507 - > 217	625	
All end 2018->end 2019		49 431 -> 142	076
L1 end 2018->end 2019		494 - > 607	
L2 end 2018->end 2019		5 194 - > 5 47	7
L3 end 2018->end 2019		18 - > 31	
Data downloads			
All data			431 075
ICOS Level 1			212 560
ICOS Level 2			38 587
Level 3			14 166
Data previews			
Timeseries			6 195
Spatial			
72			
Ship tracks			107



Figure 2 Number of unique users (left axis) and page views (right axis) per week on the CP web pages and services.



Figure 3 Geographical distribution of the CP website unique users. Next to 13.2% from Sweden the number of users from the USA (13.1%) stands out. Germany is 3rd with 8.9%, followed by Finland (8.6%) and France (6.1%). China, UK and Italy follow with around 5%.

According to the analytics 59% of the users is male, and the largest age category of visitors is 25-34 of age (41%). Only 14% uses a phone to access the website, desktops still prevail with over 84%.





Figure 4 Downloads of Level 1, 2 and 3 data products per month. Since October 2019, one IP address in Germany that downloads all L1 products on a daily basis has been excluded from the statistics which brings the monthly download count of ICOS data back to a more representative about 6000 per month.

Infrastructure support (Task 2)

The Nextcloud fileshare and the integrated document editor OnlyOffice has been adopted by the ICOS community and is now widely used, not only by the RI facilities and HO, but also by the wider communities, like MSAs, projects like EUROCOM, VERIFY and MEMO2, and the ENVRIFAIR project. At the end of 2019 the fileshare already had more than 200 active users, storing >800 000 files and using about 500 Gigabytes. The Nextcloud and OnlyOffice combo is actively upgraded to the latest versions.

The Document Management System Alfresco was continued but not actively upgraded. All documents will be transferred to the Nextcloud system in 2020.

The Exchange mail service for ICOS ERIC and the mail lists for the ICOS community were continued throughout the whole year.

Keeping track of all changes in users and roles and reflecting this in the access rights per user in the different system is an ongoing and time-consuming task. By enabling more and more to manage these administrative changes at the level where they belong, we hope to reduce the overhead, increase the speed of actualisation and reduce the communication required to keep everything up to date and the workflows smooth.

Data management and elaborated products (Task 3)

In August 2019 the second Level 2 release of ICOS Atmosphere was released by the Atmospheric Thematic Centre through Carbon Portal for 19 labelled stations and in total 49 vertical levels, almost at the same time of the first Level 2 release for ICOS Ecosystem (3 stations).

In August 2019 ICOS also released at the Carbon Portal the first public release of the observational data from the Drought 2018 task force. This data set includes eddy flux data from 28 of the 52 stations that participated in this initiative and that agreed in an early open release. The remaining data will be released early 2020 together with the 14 special issue papers in the Philosophical Transactions of the



Royal Society B on the subject. At that time also the time series data from 48 atmospheric (ICOS and non-ICOS) stations will be released. Both Drought 2018 Task Force observational time series go back for some station to 1986 up to 2018 and will provide for the first time a homogeneous and consistent dataset of historic 'ICOS-like' observations that closely connects in time with the official ICOS Level 2 products and that will allow modellers to perform model runs over longer time series.

Carbon Portal participated in a Swedish Science Centre project on promoting programming learning in high schools using real data with a focus on climate change and the UN Global Goals. ICOS in collaboration with Lund University, the Swedish Space Agency and the Swedish Science Centres has developed educational material in the form of Jupyter Notebooks using ICOS data to increase the awareness about climate change, show how ICOS data can be used to monitor carbon balance and showcase the importance of programming in handling environmental data. The notebooks focus on subjects like: understanding the Carbon Cycle (daily & annual) and drought. The educational material is to be used at Science Centres all over Sweden (20 Science Centres in total). Three Science Centres participated in the first stage of the project and are currently using the material with students. Representatives from the remaining Science Centres are to be trained during 2020 during the second phase of the project. The educational material has also been used to train high school teachers with the aspiration of them using their newly acquired knowledge in the classroom. Preparations are made to make the material available to all schools.

Carbon Portal continued to support the EUROCOM inversions and assisted in their extension to the 2018 drought year was continued by providing an update of the anthropogenic emissions based on EDGAR emission inventory, annual BP statistics on fuel use and TNO time profiles, and by extending the analysis tools in the Jupyter notebook service of CP. The inversion results were published with DOIs at CP as supporting material for two scientific papers and for further dissemination, e.g. as part of the first GHG synthesis of the European carbon budget in the VERIFY project.

During 2019 ICOS expanded its Jupyter-related services. Besides the Jupyter Hub, currently hosting 35 users, ICOS added a new service enabling users to work with ICOS notebooks without having to be registered. The service was called *Anonymous* and was destined to be used as a testing platform during presentations, seminars and workshops. It allowed users to experience the full functionality of working within a Jupyter environment with the exception that added content would be deleted after log-out or after 15 minutes of inactivity. If users wished to save their added work, they could do so by downloading the notebooks they had previously been testing. The service is run within docker containers on the ICOS server and its updating and running processes are fully automated. This ensures that all content and functionality will be restored in case of a system failure. Anonymous has successfully been tested during presentations and workshops throughout 2019.

Anonymous includes ICOS-notebooks, project-specific notebooks (e.g. RINGO flask-sampling) and educational notebooks. The ICOS-notebooks contain:

- interactive maps and plots of ICOS atmospheric data.
- forms for computing statistics over ICOS atmospheric data and visualizing the results in interactive plots.
- comparison of atmospheric model results (STILT) to ICOS atmospheric data with interactive plots.

All plots include citation strings for the depicted datasets.

Also, the project-specific collaborative Jupyter notebook service was continuously expanded and updated in close consultation with the users to support their scientific analysis and interpretation of ICOS data and products. A Jupyter notebook to support the design of flask sampling strategies for quality control of in situ atmospheric concentrations measurements and collection of samples suitable for radiocarbon analysis was developed based on STILT footprints and the Level 2 release of ICOS



Atmosphere data. This interactive notebook is available for ICOS Atmosphere station PIs for stationspecific analysis and to select the appropriate thresholds required for the implementation of the automated sampling.

The STILT footprint tool is frequently used by station PIs and scientists related to ICOS, often in combination with Jupyter notebooks, and input datasets are regularly updated to allow model simulations for the most recent year.

Strategies to extend the CP elaborated products and services to the ecosystem and ocean communities were further explored in discussions with ICOS scientists and users. The technical requirements to install a European-scale version of FLUXCOM, a tool to estimate gridded biosphere-atmosphere fluxes by upscaling ecosystem flux measurements in combination with satellite remote sensing and meteorological data deploying machine learning methods, were discussed in first meetings with the FLUXCOM development group at the Max Planck Institute for Biogeochemistry in Jena.

Training and user support (Task 4)

In cooperation with ICOS-Sweden a PhD course on carbon-balance mapping is planned for Spring 2020. The course will be organized as part of the ClimbEco Graduate Research School at Lund University. This research school is open for all PhD students. The course will focus on different methodologies used in scaling carbon monitoring measurements and application of simulation methods. Besides lectures on the different methodologies, also different tools developed at the ICOS-CP and examples of Jupyter Notebooks will be introduced to the students as part of the exercises.

In cooperation with the Lund University Science Faculty Library an on-campus course on data management was given for PhD students. The course is an introduction to basic data management covering topics like the data life cycle, Data Management Plans, FAIR principles, data publication and citation. Totally 13 PhD students participated in the course, as well as several library employees. The course, corresponding to 2 ECTS is now an official Faculty PhD course and will be given at least once a year. Developed course material will also be used in planned educational activities for the EnvriFAIR project.

Carbon Portal support was instrumental in making the Drought 2018 task force a successful community effort. CP organized (and chaired many of) the video conferences and the face-to-face meetings and informed the participants of data management practices and possibilities, and promoted and organized the data collection through the ICOS fileshare. Furthermore, CP curated the data, minted DOIs and collected and organized together with the Thematic Centers the relevant metadata. The additional effort to extend the EUROCOM inversions to the 2018 period was also supported by the CP collaboration tools and Ute Karstens.

In November 2019 the preparations started for the 5th ICOS/RINGO Summer School "Challenges in measurements of greenhouse gases and their interpretation", to be held in Hyytiälä from 9-15 May 2020. The call for participants was opened on 12 December and received more than 45 requests for participation while there is only space for 35 participants. Next to the traditional set of teachers that took part in this series of summer schools already from the start we will receive confirmed participation from many new teachers, so that we can offer an attractive and up to date program to the students.

Feedback from users is gathered from the feedback form on the website (<u>https://www.icos-cp.eu/form/detailed-feedback</u>) and by emails received at <u>info@icos-cp.eu</u>. These messages are usually answered within 24 hours. All in all, we received only about 10 non-spam feedback messages over the course of 2018. Other good feedback has been received at the MSA meetings attended by CP and the EUROCOM discussion, in which many inverse modelling users take part.



A series of workshops, training sessions and pilot tests took place as part of the Swedish Science Centre project. Here's a list of the aforementioned events where members of the ICOS CP Team were present (all events took place at Vattenhallen, Science Centre, Lund):

- 6 November 2019 (14:00 16:00) pilot session with high school students
- 14 November 2019 (10:00 16:30) one day seminar including presentations and training sessions for pedagogues from 3 Science Centres (Vattenhallen - Lund, Universeum -Gothenburg & Navet - Borås)
- 28 November 2019 (10:00 12:00) pilot session with school class,
- 28 November 2019 (16:00 19:00) training session with high school teachers
- 5 December 2019 (16:00 19:00) training session with high-school teachers
- 12 December 2019 (16:00 19:00) training session with high-school teachers

The aanonymous access to the Jupyter notebooks through the <u>https://exploredata.icos-cp.eu</u> platform has successfully been tested during several presentations and workshops. Below are some indicative examples:

- MSA Atmosphere, Paris 14-16 May 2019
- CP team visit to ICOS Head Office, Helsinki 22-23 August 2019
- Kulturnatten, Lund University Science Fair, Lund 19 September 2019
- 2nd Nordic ICOS Symposium, Gothenburg 23-25 October 2019
- Swedish Science Centre Pedagogue Meeting, Lund 14 November 2019
- MSA Atmosphere (Jupyter notebook to support implementation of the flask sampling strategy), Bologna 18-20 November 2019
- student workshops and teaching seminars at Vattenhallen Science Centre, Lund November-December 2019

Management (Task 5)

The Carbon Portal involved in 2019 a team of 18 persons, delivering a total of 11.4 fte, including the external projects (3.2 fte). The overall management, including HR and project management (including acquisition), is performed by the Carbon Portal director, who is employed by ICOS ERIC. All other CP personnel is employed by either Lund University or Wageningen University.

In regular group meetings, every two weeks, progress is discussed with all CP team members. The CP director also takes part in weekly video conferences with ICOS Head-Office and bi-weekly ICOS Head of Units video conferences. The CP Director is also part of ICOS RICom, that meets during monthly video conferences and two face-to-face meetings every year. In principle, the CP director visits Head Office every two months for a two-day face-to-face update.

Video conferences with the thematic centres have been organised based on emerging needs. Furthermore, the CP director and representatives from CP have been attending the MSA meetings from all ICOS Themes, presenting there the progress at CP and receiving feedback on the developments.

The CP project portfolio in 2018 consisted of six H2020 projects (ENVRIPLUS, SEACRIFOG, RINGO, VERIFY, EOSC-Hub, ENVRIFAIR), one national project (SITES) and one international project (COPERNICUS in-situ). The H2020 ENVRIFAIR project started on 1 January 2019. Of course, all plenary project meetings related to the CP project portfolio projects have been attended by representatives of CP.

Travel is extensive, but in order to keep our carbon footprint low, whenever possible meetings are arranged by video conferencing. When in the office CPD alone has on average 2-3 and sometimes up to 5 video conferences per day.

Extensive development work is being carried out through the H2020 projects, that are all beneficial to ICOS with regards to data management and eScience, as well as providing links to EUDAT (CDI) and the other e-infrastructures that will play important roles in the upcoming European Open Science Cloud



(EOSC). Maggie Hellström is very active in representing ICOS in several Research Data Alliance working groups as well as in GEDE (Group of European Data Experts in RDA Europe).

The CP director is active as chair of the WMO GAW scientific advisory board for greenhouse gases, member of the executive steering group of WMO IG3IS, member of the expert group of the H2020 CHE project and member of the advisory board of the MEMO2 project. Also, this year the now 15th WMO GAW Greenhouse Gas Bulletin was composed by the WMO SAG on Greenhouse Gases and coordinated by CP, with this year as highlight the use of isotopes to constrain the influence of fossil fuels on the global CO₂ budget. The bulletin was released just before the COP meeting in Spain. As always, this edition of the bulletin received a lot of attention in the international press.

CP is also acting as representative of ICOS in the Copernicus in-situ project lead by EEA. In this framework we initiated a workshop and resulting report (to be published early 2020) from this project on the sustainability of the TCCON network in Europe where the integration of TCCON in the ICOS network is investigated and discussed.

AV and MH are active as representatives of ENVRI RIs in the EOSC working groups on Architecture, AAAI and PID.

CP hired one new employee in Lund as project manager for work package 5 and 6 in ENVRIFAIR, Angeliki Adamaki, who has a strong background in data management for solid earth science. Scientific programmer Zhendong Wu was hired part time (25%) from Lund University to assist in SEACRIFOG and EOSC-Hub tasks. In September Dr. Zheng Duan started a new tenure track position at Lund University in September 2019 that is paid for 30% from CP budget. He will concentrate on the application of remote sensing and satellite information in carbon cycle science and work together with the rest of the team on elaborated products.

Meetings attended in 2019

- 8+9 Jan: Helsinki (AV) CPD visit to HO
- 14-16 Jan: Prague (AV, MH, HL) Kick-off meeting ENVRIFAIR (several presentations)
- 31-Jan: Brussels (AV) Kickoff EEA Copernicus in-situ project 2019
- 4-7 Feb: Milan (AV) RI-Train leadership training
- 22 Feb: Amsterdam (AV) Drought 2018 task force face-to-face meeting
- 26-28 Feb: Paris (AV) RICom face-2-face meeting at LSCE
- 12-14 Mar: Reading (AV) CHE and VERIFY annual meeting
- 18-19 Mar: Southampton (HL) MSA Ocean
- 20-22 Mar: Southampton (AV, HL, UK, CD) RINGO annual meeting
- 25-28 Mar: Helsinki (AV, MH) ENVRIplus week
- 8-12 Apr: Vienna (AV) EGU
- 10-12 Apr: Prague, (HL) EOSC-hub week
- 15 Apr: Darmstadt (AV) TCCON sustainability meeting
- 25 Apr: Copenhagen (AV) CIS2 workshop at EEA
- 14-16 May: Paris (AV, UK) MSA Atmosphere
- 21-22 May: Paris (AV) ICOS GA
- 23+24 May: Nice (AV) MSA Ecosystem
- 11-12 June: Amsterdam (AV) ENVRIFAIR Marine workshop
- 13-14 June: Amsterdam (AV) Non-CO2 Greenhouse Gas Conference
- 19 June: Copenhagen (AV) EEA Copernicus in-situ team meeting
- 22+23 Aug: Helsinki CP team visits Head Office
- 1-6 Sep: Jeju, South Korea (AV) WMO GAW GGMT meeting and SAG face2face
- 24-26 Sep: Zürich (AV) RICom face2face



- 1 Oct: Amsterdam (AV, MH) ENVRIFAIR EB face2face
- 15-16 Oct: Lund (KP, CD, AA) Swedish e-science academy
- 15-18 Oct: Paris (AV,UK) IG3IS/TRANSCOM workshop
- 24+25 Oct : Göteborg (AV, KP, HL) Nordic ICOS Symposium
- 30 Oct: Lund (AV, MH, AA) ENVRI FAIR WP05 Review Workshop (organisers)
- 4-5 Nov: Paris (UK) VERIFY GHG synthesis workshop
- 11-14 Nov: Geneva (AV) WMO GAW Scientific Steering Committee meeting
- 18-20 Nov: Bologna (AV) MSA Atmosphere
- 25-27 Nov: Budapest (AV) EOSC Symposium
- 27-28 Nov: Kiel (UK) MSA Ocean
- 9-13 Dec: San Francisco (AV) AGU Fall Meeting
- 11-12 Dec: Paris (CD, AA) ENVRI FAIR Atmosphere workshop (changed to e-meeting)

Significant publications in 2019

- Manuscript: Persistent Identification of Instruments, Submitted to DSJ RDA Results (Special Collection), Markus Stocker, Louise Darroch, Rolf Krahl, Ted Habermann, Anusuriya Devaraju, Ulrich Schwarzmann, **Claudio D'Onofrio**, Ingemar Häggström
- Agustí-Panareda, Anna, Diamantakis, Michail, Massart, Sébastien, Chevallier, Frédéric, Muñoz-Sabater, Joaqu'in, Barré, Jérôme, Curcoll, Roger, Engelen, Richard, Langerock, Bavo, Law, Rachel, Loh, Zoë, Morguí, Josep Anton, Parrington, Mark, Peuch, Vincent-Henri, Ramonet, Michel, Roehl, Coleen, Vermeulen, Alex T, Warneke, Thorsten and Wunch, Debra, Modelling CO2 weather why horizontal resolution matters, Atmospheric Chemistry and Physics Discussions, 1-48, 2019
- López-Ballesteros, A., Beck, J., Bombelli, A., Grieco, E., Lorencová, E. K., Merbold, L., Brümmer, C., Hugo, W., Scholes, R., Vačkář, D., Vermeulen, A., Acosta, M., Butterbach-Bahl, K., Helmschrot, J., Kim, D.-G., Jones, M., Jorch, V., Pavelka, M., Skjelvan, I., & Saunders, M. (2018). Towards a feasible and representative pan-African research infrastructure network for GHG observations. Environmental Research Letters, 13(8), 85003. https://doi.org/10.1088/1748-9326/aad66c
- Monteil, G., Broquet, G., Scholze, M., Lang, M., Karstens, U., Gerbig, C., Koch, F.-T., Smith, N. E., Thompson, R. L., van der Laan-Luijkx, I. T., White, E., Meesters, A., Ciais, P., Ganesan, A. L., Manning, A., Mischurow, M., Peters, W., Peylin, P., Tarniewicz, J., Rigby, M., Rödenbeck, C., Vermeulen, A., and Walton, E. M.: The regional EUROpean atmospheric transport inversion COMparison, EUROCOM: first results on European wide terrestrial carbon fluxes for the period 2006–2015, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-1008, in review, 2019.
- Ramonet et al, PTRS B, accepted

Other publications in 2019

- Poster presentation: European Greenhouse Gas Measurements, Discover –Visualize –Share -Collaborate, Swedish e-Science Academy, Lund 15-16 October, Karolina Pantazatou, Angeliki Adamaki, Claudio D'Onofrio
- Whitepaper (not published, internal, 2019): Collaboration and Harmonisation of ICOS and NEON Data Portal (The National Ecological Observatory Network (USA), Claudio D'Onofrio, Cove Stuart, Christine Laney
- Seminar, presentation: ICOS ERIC Overview, Structure, Integration in the European ENVRI Landscape, Claudio D'Onofrio, NEON, Boulder, CO, November 2019)
- Seminar, presentation: ICOS Carbon Portal Data & Metadata flow: from in-situ measurements to triple store, Claudio D'Onofrio, NEON, Boulder, CO, November 2019)



- H2020-InfraEOSC-2019-1, 863026, PROV4R, Provenance Services for Research. Collaboration to write project proposal. Project rejected.
- Poster presentation: ICOS Carbon Portal: data and services to support carbon cycle sciencelGI3IS/TRANSCOM workshop, 15-18 October, Paris, Ute Karstens, Karolina Pantazatou, Alex Vermeulen, Naomi Smith, Christoph Gerbig, Frank-Thomas Koch, Guillaume Monteil
- RINGO Deliverable report D1.3, An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling, I. Levin, U. Karstens, F. Maier, M. Eritt, D. Rzesan, S. Conil, D. Kubistin, M. Lindauer, S. Hammer
- ENVRIPLUS deliverable D6.3. Hellström et al: <u>Report on identification and citation service case</u> <u>studies</u>.
- Seminar, invited presentation: ICOS flux data as an example for an educational tool to inform students about carbon cycle science, Alex Vermeulen, Ute Karstens, Harry Lankreijer, Karolina Pantazatou and Carbon Portal Team, 2nd Nordic ICOS Symposium, Gothenburg 23-25 October 2019.
- WMO Greenhouse Gas Bulletin (GHG Bulletin) No. 15: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2018 (2019)
- Seminar, presentation: ICOS Carbon Portal Working together on large datasets, Maggie Hellström, Karolina Pantazatou, Seminar on scientific collaboration on large datasets, Max IV Laboratory, Lund 9 December 2019.
- University Science Fair: Understanding the Carbon Cycle using ICOS data and Jupyter notebooks, Karolina Pantazatou, Kulturnatten, Lund 19 September 2019.
- Conference presentation: The ICOS Atmosphere use case: From raw data to knowledge of societal relevance, Maggie Hellström, Ute Karstens, Karolina Pantazatou, Alex Vermeulen and Naomi Smith, 11th International Symposium on Digital Earth, Florence, September 26, 2019
- Poster presentation: Not just a lot of "hot air": How ICOS observations are helping to inform society about climate change, Maggie Hellström, Ute Karstens, Karolina Pantazatou, Alex Vermeulen and Naomi Smith, 14th plenary of the Research Data Alliance, Helsinki, October 23-25, 2019
- Invited seminar presentation: Data management aspects of the ICOS near-realtime data flow, Maggie Hellström, Pufendorf Advanced Studies Group on Real-time DATA seminar, Lund University's Pufendorf Institute of Advanced Studies, October 29, 2019
- Seminar, presentation: Programming exercises in Python using ICOS data Focus on Climate Change-related problems and UN Global Goals, Swedish Science Centre Pedagogue Meeting, Vattenhallen, Lund 14 November 2019, Karolina Pantazatou, Harry Lankreijer.



Atmosphere Thematic Centre (ATC)

Data collection and availability (Task 1)

Level 0 data transfer (Task 1.1)

New station and instrument registrations took place and new data transfers have started.

- The Steinkimmen German station has been registered and has started to transfer GHG data, meteorological data and diagnostic data.
- The Weybourne English station has been registered and has started to transfer GHG data and meteorological data
- The Lutjewad Dutch station to transfer meteorological data and diagnostic data.
- The Ochsenkopf German station has been registered and has started totransfer GHG data, meteorological data and diagnostic data.
- The Karlsruhe German station has started to transfer meteorological data.

Maintenance

- Maintenance of the network data.
- Manage multiple instrument movements on different sites as well as change of processing parameters.

Developments

- The weekly GHG data reports for the PIs have been enhanced. A new "File Status Summary" ٠ section has been added. It presents whether the expected files were received, received with delay or blacklisted for any reason.
- Last fall, a new column has been added to "File Status Summary" section to presents if received files were corrupted.
- A new weekly report for meteorological data has been added. It contains the new "File Status • Summary" section of each sampling height.

Weekly processing report: 2019-10-31-2019-11-06

Automatic email, v	weekly report	of the proces	sing of the	instrumen	t 472 d	ata on site Tf	RN.
File status sum	nmary						
	Date	Blacklisted	Received	On time*	Delay	Corrupted	
	2019-10-31	NO	YES	YES		NO	
	2019-11-01	NO	YES	YES		NO	
	2019-11-02	NO	YES	YES		NO	
	2019-11-03	NO	YES	YES		NO	
	2019-11-04	NO	YES	YES		NO	
	2019-11-05	NO	YES	YES		NO	
	2019-11-06	NO	YES	YES		YES	

* File is considered late if received after the next day at 9h (UTC)



NRT data production (Task 1.2)

A total of 29 stations are connected to ATC, sending their data to ATC and, consequently, are able to be processed in NRT mode. This represents 11411 (+29% compared to 2018) raw archive files (~81Go, +26% compared to 2018, for a mean of 7.6Mo/station/day) processed for an availability rate of ~0.97 (+0.03 compared to 2018) for 23 (+1 station compared to 2018) stations which transmit their data over the complete 2019 year.

NRT data visualization and distribution (Task 1.3)

NRT data visualisation can be accessed on ICOS ATC website [https://icos-atc.lsce.ipsl.fr/dp], through the page of the NRT data products generated at ICOS ATC, and/or, depending on the product, directly on the panel board of the concerned station (accessible via its trigram code).

In 2019, 68 families of graphical NRT Data Products, (~ 9502 products in total, which represent an increase of +23%/2018, for ICOS network stations) are produced daily from NRT measurements (total volume of 1.48Go (+0.48Go/2018) and freely available on the ATC website for station monitoring and diagnosis.

Those Data Products are helpful for PIs to verify the status of their stations. In total, for the year 2019, nearly ~3100 (+600/2018) users have interacted with ATC's website, for ~46000 (+6%/2018) page views.

Level 2 data production (Task 1.4)

The new Level 2 (2019-1 release final quality controlled observational) data from the atmospheric network has been released on 1st August 2019 by the ICOS Atmosphere Thematic Centre. The data concerns the stations Gartow, Hohenpeißenberg, Hyltemossa, Ispra, Jungfraujoch, Křešín u Pacova, Lindenberg, Lutjewad, Monte Cimone, Norunda, OPE, Pallas, Puy de Dome, SMEAR-II, Svartberget, Torfhaus, Trainou, Utö and Zeppelin Observatory. It contains CO2, CH4, CO data as well as meteorological data for the labelled stations. 14^c data where available were also included. The time coverage of the data is September 2015 - April 2019. The start date varies for each station, it corresponds to the moment the station is ICOS compliant. A DOI is minted for the complete collection of this release that contains the final quality controlled hourly averaged data for the mole fractions of CO2, CO and CH4 and meteorological observations measured at the relevant vertical levels of the measurement stations, and where available 14C in CO2 in two-weekly integrated samples, for the years 2016-2019. All stations follow the ICOS Atmospheric Station specification V1.3 (https://www.icos-ri.eu/fetch/ba12290c-3714-4dd5-a9f0-c431b9900ad1;1.0) and are certified as ICOS atmospheric stations Class I or II. Data processing has been performed as described in Hazan et al., 2016 (doi:10.5194/amt-9-4719-2016). The data can be found and previewed through at the Carbon portal. The L2 data collection can be found at doi:10.18160/CE2R-CC91.

Network coordination, training and development (Task 2)

Instrument testing (Task 2.1)

ATC Metrology Lab (MLab) has performed all the instrument testing required for the station labelling, including: leakage rate, instrument precision, linearity and drift, short term and long-term repeatability, sensitivity to inlet pressure, atmospheric pressure and temperature, H2O correction. ATC has provided test report and a certificate of compliance to all the instrument tested.



ATC has improved its internal leak test procedure for GHG analyzers. Based on the Metrology Lab and field tests performed to characterize the Nafion dryer in different conditions, ATC has defined and validated a Nafion setup for the ICOS atmospheric station to avoid the regular assessment of the water vapor correction in the field. Indeed, ATC highly encourage station PI to use such setup to make the field operation easier for station PI (no water vapor correction assessment test in the field) and also simplify ATC data unit work to manage the water vapor parameter (no reprocessing when water vapor correction is updated). Thanks to ATC technical support, the ICOS atmospheric station network started to implement the Nafion dryer.

Based on several tests at Mlab and in the field, ATC has optimized the measurement setup and procedure for N2O analysers. ATC has proposed N_2O as a new ICOS mandatory parameter for class 1 station.

Following the work with other groups (Cabauw, weybourne UK, Dave Griffith) on the validation of a sampling setup and procedure for ECOTECH Spectronuous FTIR, ATC has demonstrated during the MSA the suitability of this GHG spectrometer for the ICOS atmospheric station network. Based on this working group (leaded by ATC) report, the ICOS community as validated the use of the ECOTECH Spectronuous for the ICOS network.

ATC determined an in-situ testing strategy on the station sampling system in order to detect and quantify any measurement bias related to these parts which are out of the scope of the automatic quality control system (mainly based on the frequent measurement of a dedicated QC gas: the target gas). The atmospheric stations started this additional requested Quality Control tests on a regular basis. ATC is supervising the performance of the tests in the field and compile all the corresponding test reports.

Once the stations are labelled, ATC carry on controlling the quality of the data provided by the station by checking the corresponding ATC data product in interaction with the station PIs.

ATC has tested 2 different analyzers from LICOR using OF-CEAS technology as a possible candidate for CO2 and CH4 measurement: LI-7810 ($CH_4/CO_2/H_2O$) and LI-7815 (CO2/H2O). The corresponding test report will be distributed to the ICOS community and discussed during the next MSA.

ATC carry on testing several mid and low-mid cost sensors for CO_2 and CH_4 like MirSense MultiSense photoacoustic sensor, Senseair HPP, Figaro CH4 Metal Oxide sensor... This prospective work takes place for new domain of application (mobile measurement, dense low-cost sensor network for urban area or industrial site...).

Atmospheric station audit (Task 2.2)

ICOS Mobile Laboratory is one of the subunits of the ICOS RI Atmosphere Thematic Centre (ATC). It is physically located in the Finnish Meteorological Institute and mainly funded by the Ministry of Transport and Communication in Finland. The main task is to conduct quality control (QC) by parallel measurements at atmospheric stations (AS).

Saclay (SAC) was audited in 2019. In addition to normal audit activities, FTIR intercomparison between ICOS Metrology laboratory and Mobile laboratory spectrometers was conducted aiming at improving Mobile laboratory FTIR performance.

We prepared and finalised the audit report of Ispra (IPR), which was audited in 2018. Our new ICOS sample air drier was tested to replace the original Nafion drier of the FTIR analyser. We started preparation for the next audit at Lindenberg (LIN) to be conducted in 2020.



One task of Mobile Laboratory was to monitor calibration scales between ICOS CAL and Mobile Laboratory, together with WMO/CCL standards at Mobile Laboratory using travelling cylinders.

Manpower for running the Mobile Laboratory is planned to be two full-time persons. Unfortunately, two persons moved to other duties and practically there was only one full time person in 2019.

Training activities for ICOS atmospheric measurements (Task 2.3)

After several consultations (during the 2 MSA and by emails), ATC organized only one training session in 2019 with Pis from Italy, Norway, UK, Germany, Denmark and Sweden. All the initial training requested for new ICOS comers and step 2 labelling have been provided by ATC.

ATC has offered a short training workshop on Nafion dryer during the MSA in Bologna. Indeed, as MSA gather all the station PI and some of the technical staff, it is a good opportunity to touch all the atmospheric community on very specific topics which can be dealt on short format (coffee breaks...). ATC is going to continue to offer such short training sessions on specific topic during MSA. Moreover, ATC will continue to offer standard training at ATC in order to answer the demand of new incomers and also to deal with the technical staff turnover. In addition, ATC is working on training session dedicated to new specific topics (instrumentation, sampling setup) and refresh on topics already dispensed in the initial training session in order to maintain atmospheric station staff well trained and achieve the best data quality within the European ICOS network.

Activities and plan reported to the DG, RI Com and General Assembly (Task 2.4)

The ATC workplan, reports and associated budgets were provided to ICOS HO. The ATC attended both General Assemblies that took place in 2019 as well as the two RICOM face to face meetings.For the RINGO project, ATC delivered an important document titled "Scientific and technical concept for the integration of ground based greenhouse gas remote sensing into ICOS and resulting costs". The potential synergies between ICOS and TCCON have been presented to the ICOS GA.

Station labelling process, Steps 1 and 2 (Task 2.5)

- Labelling of 6 new ICOS Atmosphere stations in 2019: KIT, LUT, OXK, RUN, STE, UTO
- An ICOS Atmosphere labelling paper has been drafted by C. Yver-Kwok from ATC.

Significant publications in 2019

Ramonet et al.,2019. "The fingerprint of the summer 2018 drought in Europe on ground-based atmospheric CO₂ measurements", Philosophical Transactions B.



Ecosystem Thematic Centre (ETC)

Highlights

• Two new members joined the ETC: Fana Michilsens (Antwerp) and Nadia Vendrame (Viterbo). Both are following the labelling process and Level2 data preparation.

Data collection and availability (Task 1)

The data collection continued with an increase of sites and data submitted to the Carbon Portal and to the ETC. All the labelled stations and the one under labelling submitted also the metadata and the additional data needed for the processing (like the DHP and ceptometer files). Vegetation samples and soil samples have been collected by respectively 26 and 4 stations, and submitted to the ETC labs in France for the analysis.

For the first year, Level2 data has been produced and distributed through the CP and the code for the NRT applied for the first part of the analysis (quality control) and under implementation in the CP. All the codes are on GitHub.

Raw data transfer (Task 1.1)

<u>Continuous data</u> (eddy covariance and meteorology): the 13 labelled stations are submitting NRT data directly to the Carbon Portal after a quality check and confirmation performed by the ETC. At the time of the report preparation, in addition to these labelled stations, additional 9 are submitting continuous raw data daily (in the Step2 process of the labelling).

<u>Ancillary data and metadata</u>: all the labelled stations, including the Associated, submitted the requested large number of metadata describing the sensors and setup, the changes and the other biological information. Seventeen stations currently in Step 2 of the labelling also submitted at least part of the metadata. All the data are archived in the ETC database and will be synthesized and transferred to the CP together with the Level 2 data production. The ancillary data on ecosystem characteristics (species composition, biomass, Green Area Index, trees position, litter, etc.) that have been submitted by stations are quality checked by ETC. Also, in 2019 different forest sites used the FieldMap instrument provided by the ETC.

<u>Digital Hemispherical Pictures and ceptometer files</u>: DHP and ceptometer files have been submitted by stations in Step2. For both data types the routine and tool to upload them in the CP system and retrieve the PID is active.

<u>Vegetation samples</u>: 26 ecosystem stations collected and submitted a total of 934 samples to the ETC labs (in 2017 there were 10 stations and 318 samples, in 2018 21 station and 671 samples). This is a trend that although slowly is growing and will grow more in the next years with the increase of number of stations labelled. All these samples are labelled and archived, for 80% of the samples the analysis results are already available and loaded in the database.

<u>Soil samples</u>: in 2019 we received soil samples from four sites for a total of 375 samples and the analysis are completed for 215 and under finalization for the others.



NRT data production (Task 1.2)

The first part of the NRT data preparation is operational with an automatic check of all the raw data every morning. The check, that is controlled by a complex code, evaluate the file format, the file content and the compliance between the metadata and the data. The code runs every morning between 6 and 7 AM CET and send an automatic message to the station team with the results. The same code prepares also the files for the NRT fluxes calculation and does the processing of the meteorological data.

The fluxes calculation is controlled by a different suite of codes that has been release in GitHub and at the moment of preparation of this report under implementation in the Carbon Portal machines. The example of NRT data product has been prepared and the details about the distribution and visualization on the CP are under discussion.

NRT data visualization and distribution (Task 1.3)

This task will be removed in the new list of activities because it has been decided to have the data visualization only in one place and more specifically in the Carbon Portal, that has this already implemented in an efficient way.

Level 2 data production (Task 1.4)

The Level2 data production started with the first three labelled sites in 2018 and the Level2 products released in March 2019.

<u>Eddy covariance and meteo</u>: the processing has been applied to the raw data and a new QAQC scheme applied. The Level2 product is composed by two files: one is a format that is following the standard of the FLUXNET community and for this reason fully compatible with the other international networks. The other is an archive with a more detailed set of results, also very detailed and unique. The code used for the processing and quality control is also published in GitHub in the ICOS ETC repository.

<u>GAI and Biomass</u>: for the same labelled sites all the DHP and ceptometer data have been processed and the results aggregated for the Level2 product that is also following an international standard.

Overall the experience highlighted the critical aspects and feedbacks have been collected in order to improve the product in the next Level2 release expected for March 2020.

Network coordination, training and development (Task 2)

The activities in this task have been predominant also in 2019. Respect to 2018 however less efforts have been put in the Instructions, protocols and templates while the labelling required more time and work due to the increase of the number of stations in the process.

In general, the labelling has been completed for additional 12 stations and 17 are in the process.



Training and information of the ICOS ecosystem network (Task 2.1)

Nine Ecosystem Instruction documents have been revised and updated in 2019 and one new Instruction document on phenology measurements shared in the MSA for comments before its finalization that will happen in 2020.

Similarly, 13 templates for the metadata (BADM) have been revised and improved, in particular in the explanations and rules. One of the most important changes have been the specification of the exact model of each single sensor used in order to improve the traceability of the data. This step required a large effort by the ETC members to translate all the contents already acquired and the preparation of the Frequently Asked Question document for the station teams.

The assistance to the network continued with a daily email exchange with the station teams and specific WebEx and teleconferences all the time this is needed or requested. Also, in 2019 the ETC members participated in the MSA meeting and offered training in the metadata handling and preparation.

Activities and plan reported to the DG, RI Com and General Assembly (Task 2.2)

The activity and financial plan for the 2020 and the report of the 2018 activities (including the financial report) have been prepared and submitted to the DG and HO using the agreed template and guidelines approved by the GA.

ETC participated to the spring and fall GAs presenting the results obtained and situation of the activities (info day) and meeting the Advisory Board. ETC participated to the RICom meetings and teleconferences. Large part of the efforts in 2019 have been also dedicated to the preparation of the Strategic Plan and 5 Years plan.

Station labelling process, Steps 1 and 2 (Task 2.3)

The activities on the labelling continued in 2019 with stations that entered the process and stations proposed for labelling. In particular:

- Three Associated stations started the labelling process and have been positively evaluated. The stations are now preparing the data in order to complete the labelling.
- One Class1 and two Class2 stations completed the Step1 of the labelling and two of them started the Step2 (one Class1 and one Class2). Also, another Class2 station that ended the Step1 in 2018 started the Step2
- A total of 12 stations completed the labelling process in 2019 and have been approved by the GAs. In particular four Class1 (DE-RuS, DE-Hai, CH-Dav and FR-Fon), four Class2 (DE-Svb, FR-Bil, IT-SR2 and SE-Deg) and four Associated (DE-Kli, GF-Guy, FI-Kmp and FR-LGt). It is worth to note that 8 of them have been approved at the fall GA, confirming the general need of the growing season to complete the process.
- There are 17 Class1 and Class2 stations that are currently in the Step2 of the labelling and that have constant interaction with the ETC for all the aspect connected to the process.

Other important activities not planned

In 2019 an additional and not planned activity have been the preparation of the ecosystem data for the 2018 European Drought analysis. Long time series with data up to 2018 (included) have been collected,



quality controlled and processed with the standard ICOS and FLUXNET tools for 52 stations in Europe (including non-ICOS stations) and the results shared in the ICOS Carbon Portal.

This activity gave large visibility to ICOS and also proved the capacity of fast reaction in case of scientific emerging interests require delivery of data in short time. The activity was possible also thanks to the organization of the processing that is ongoing in the ICOS ETC and that has a number of steps automatized. The only time-consuming phase that is not easy to optimize is the data submission issues (formats, quality etc.) that requires a continuous exchange with the station teams. This problem is however almost no present for the ICOS Class1 and Class2 stations where the data are continuously checked and the raw data shared.

Significant publications in 2019

- Knox S., ... Papale D, Trotta C., et al. (2019). FLUXNET-CH 4 Synthesis Activity: Objectives, Observations, and Future Directions. BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY, vol. 100, p. 2607-2632, ISSN: 1520-0477, doi: 10.1175/BAMS-D-18-0268.1
- Ariza-Carricondo C., ... De Beeck M.O., Gielen B., Vitale D., Papale D (2019). A comparison of different methods for assessing leaf area index in four canopy types. CENTRAL EUROPEAN FORESTRY JOURNAL, vol. 65, p. 67-80, ISSN: 2454-0358, doi: 10.2478/forj-2019-0011
- Vitale D., Bilancia M., Papale D (2019). A Multiple Imputation Strategy for Eddy Covariance Data. JOURNAL OF ENVIRONMENTAL INFORMATICS, vol. 34, p. 68-87, ISSN: 1684-8799, doi: 10.3808/jei.201800391
- Vitale D., Bilancia M., Papale D (2019). Modelling random uncertainty of eddy covariance flux measurements. STOCHASTIC ENVIRONMENTAL RESEARCH AND RISK ASSESSMENT, vol. 33, p. 725-746, ISSN: 1436-3259, doi: 10.1007/s00477-019-01664-4
- Keenan T.F., ... Papale D, et al. (2019). Widespread inhibition of daytime ecosystem respiration. NATURE ECOLOGY & EVOLUTION, vol. 3, p. 407-415, ISSN: 2397-334X, doi: 10.1038/s41559-019-0809-2
- Billesbach D.P., ... Papale D, et al. (2019). Effects of the Gill-Solent WindMaster-Pro "w-boost" firmware bug on eddy covariance fluxes and some simple recovery strategies. AGRICULTURAL AND FOREST METEOROLOGY, vol. 265, p. 145-151, ISSN: 0168-1923, doi: 10.1016/j.agrformet.2018.11.010

1-3 Scientific Highlights from 2019

- The 2018 European Drought collection processed and distributed
- The first Level2 data released


Ocean Thematic Centre (OTC)

Highlights

- Start of 2 new staff members in Bergen, Richard Sanders as the OTC Director and Tobias Steinhoff as the ICOS OTC Engineer.
- UK formally joined OTC in summer 2019. This brought in administrative experience (Jess Thorn, University of Exeter), high level academic leadership (Professor A. Watson, FRS, University of Exeter) and strong technological expertise from NOC
- Funding issues: A new funding model for calibration gas initiative including resource allocation to membrane station-based stations was accepted by GA in September 2019. Plan for unspent funds (new gas bottles and compressor, other investments to support membrane sensors, retain some as contingency reserve) in place. Devised strategic plan to address key issue facing network of lack of sustained funding.
- Projects: ICOS OTC data unit became partner in H2020 BlueCloud, EnvriFair and EuroSea. Further, multiple (at least 3) future funding proposals in 2020/21 to support OTC/ ICOS operations were identified
- Establishing an operational data flow towards the ICOS Carbon Portal
- Data delivery to SOCATv2020, to the UN Sustainable Development Goal target 14.3 about ocean acidification and establishing an operational data flow towards Copernicus Marine Environmental Monitoring Services for labeled SOOP/VOS OTC lines
- Awarded free SailDrone mission in collaboration with GEOMAR. Showcase with Saildrone and ICOS OTC data unit to QC carbon data from SailDrone, publish them in the CP and to make the available to Copernicus Marine Environmental Monitoring Services

Data collection and availability (Task 1)

The OTC data flow follows all details as described in the Data Life Cycle document by producing L0, L1 and L2 data for labeled ICOS OTC stations. A central part for achieving this task has been the development of QuinCe, an online tool for the upload, processing and quality control of data from participating stations. This tool has been released in August 2018 and is being further optimized.

Data that cannot be delivered, for unforeseen reasons, via the operational routines, QC tasks will be done using established routines, that were used prior to the operational phase. This will require more manual work and interaction with the PI and OTC staff, and will imply that not all steps as described in the Data Life Cycle document can be followed for pragmatic reasons. The method applied will still ensure a steady data flow.

Development of a KPI (key performance indicators) system for tracking the quality of labeled stations to be able to track long-term performance.

Raw and level 0 data transfer (task 1.1), NRT data visualization and distribution (Task 1.2) and Production and transmission of L2 data (Task 1.3)

Before QuinCe was fully developed, OTC accepted level 0 data (L0; raw data) and level 2 data (L2; final processed and quality-controlled data, i.e. QCed data) directly from the PIs. Since QuinCe is operational for SOOP/VOS, the PIs provide only L0 data, which is processed to produce level 1 data (L1; processed and automatic QCed data), Near Real Time (NRT) data, and L2 data by the OTC following the procedure described in the Data Life Cycle document. Automated data reduction and quality control is based upon community agreed Best Practices and Standard Operating Procedures.



Currently OTC receives NRT and delayed mode L0 data from labeled SOOP/VOS lines and data is automatically submitted to the ICOS Carbon Portal and Copernicus Marine Environmental Monitoring Services on daily basis.

While an operational data flow (LO and L1) has been established for labeled SOOP/VOS stations, it was decided to use the L2 data as QCed by station PIs for the integration in SOCAT since the operational data flow was achieved in September 2019. An operational data flow towards SOCAT will start in 2020. 73 L2 data files from 8 ICOS OTC stations were submitted to SOCATv2020 which will be published in 2020.

Network coordination, training and development (Task 2)

The new ICOS OTC engineer, Tobias Steinhoff, started in February 2019 on a 50% position. In preparation for the ICOS OTC pCO2 instrument inter-comparison in 2020 several meetings took place. After it was decided that the inter-comparison will take place at the Marine Station Ostende (MSO) at the Flanders Marine Institute (VLIZ) the facilities were visited two times to conduct several tests.

Technology developments

Socratis Loucaides from the National Oceanography Centre in the UK has taken over as the new ICOS-OTC technology lead. During the last year new sensor technology for autonomous monitoring of carbonate chemistry parameters have been in development with funding from UK and EU grants. More specifically, prototype sensors for the measurement of total alkalinity (TA), dissolved inorganic carbon (DIC) and pH have been developed and integrated on autonomous platforms including AUVs, ROVs and benthic landers. TA and pH sensors have also been tested during a cruise to the PAP observatory and further funding is being sought to test these sensors at the VLIZ observatory over longer periods. Work is underway to improve the quality of pCO2 measurements at fixed observatories by developing new technology for calibrating and validating membrane co2 sensors prior and post deployment and collecting samples periodically while sensors are deployed. New technology has been presented at the 2019 MSA meeting at NOC and the ICOS sensors workshop in Kiel and to the wider community at OceanObs 2019 and Marine Autonomous Technology Showcase.

Network design

Ship Liaison not a high priority task due to lack of funding in the network. But there are ships available.

Meetings, training and interactive discussion groups (Task 2.1)

A training course on a suite of biogeochemical sensors was held in Krisitneberg, Sweden, in June 2019. The course was a joint effort between IOCCP and BONUS-INTEGRAL, and OTC contributed with a teacher and a suite of sensors and instruments for the practical training. The course included 28 participants and 16 teachers, and the ocean variables of interest were pH, pCO2, oxygen, and bio-optics.

The 2nd ICOS OTC Sensor workshop took place at GEOMAR Helmholtz Center for Ocean Research Kiel/Germany in November 2019. During the workshop three companies (Pro Oceanus/Canda, SubCtech/Germany and Sunburst Sensors/USA) presented their instruments and offered hands-on training. The workshop offered the opportunity for ICOS and non-ICOS scientist to interact directly with sensor manufacturers.



Meeting organized or attended:

- Instrument manufacturers workshop organized in Kiel alongside ICOS MSA/OTC meeting November 2019
- Science symposium of whole network organized ICOS MSA/OTC meeting, Southampton (UK), March 2019
- Oceans MSA held in Southampton During RINGO meeting. OTC session included discussion of distinction between Class 1 and Class 2 and a mini science symposium focused on key ICOS related results
- Industry Science Observing Forum Organized in Southampton March 2019
- Attended IOC Meeting on Ocean C cycle and invited to coordinate section of report on observing network.
- Attended matchmaking event in Portugal with view of writing grant to either work on Blue Carbon type work as suggested by RICOM or to supporting early stages of Portuguese station
- Joined workshop on quality control procedures with the FerryBox network

Training and information of the ICOS ocean network (Task 2.2)

Station visits took place:

FOS Thornton buoy (Belgium) and SOOP Simon Stevin in February 2019

SOOP Trans Carrier in June and July 2019

Activities reported to the DG, RI Com and General Assembly (Task 2.3)

Station labelling process Steps 1 and 2 (Task 2.4)

The ocean ICOS network consist of 21 stations from 13 European institutions within 7 countries. All stations have passed step 1 of the labelling sequence, while 5 stations have passed step 3 and been accepted by GA as ICOS stations. In 2019, OTC put effort into evaluating data and metadata from 5 of the remaining ocean stations, but due to technical challenges at the stations and thus, lacking data, none of these fulfilled the requirements for step 2 of the labelling sequence. The station evaluation will continue through 2020.

As part of the OTC effort to validate the fixed ocean stations (FOS), the Saildrone mission ATL2MED (https://www.saildrone.com/mission/atl2med) started at Cape Verde in November 2019. Then, two unmanned 7 m long sailboats equipped with a suite of sensors and instruments for ocean and meteorological measurements were launched. The aim of this mission is two-fold: the first part, led by GEOMAR (DE), focusses on eddies off west Africa, and the second part, led by OTC, focusses on validation of FOS measuring carbon. Five of the ICOS ocean stations will participate in the mission and thus be visited by the sailboats. The mission is a joint effort between GEOMAR (DE), OTC, OSCM (CV), PLOCAN (ES), Instituto Hidrografico (PT), LOV (FR), CNRS (FR), Sorbonne University (FR), OGS (IT), CNR-ISMAR (IT), and CNR-ISSIA (IT). At the end of 2019, the sailboats were heading for the Canary Islands, and in April 2020 the mission will end in Trieste, northern Adriatic.

The work towards including the Repeat Ocean Section (ROS) as an ocean station category was put on hold in 2019, but OTC aims at solving the issues regarding station contribution and responsibility in the not too far future. The Flux Towers consist of a marine part (buoy/mooring) and a terrestrial part (flux tower), and thus, produces both marine and terrestrial data. The marine data from these stations



(currently only one station in this category) are submitted to the OTC, while the terrestrial data goes to the ETC.

Significant publications in 2019

- Steinhoff T, T. Gkritzalis, S.K. Lauvset, S. Jones, U. Schuster, A. Olsen, M. Becker, R. Bozzano, F. Brunetti, C. Cantoni, V. Cardin, D. Diverrès, B. Fiedler, A. Fransson, M. Giani, S. Hartman, M. Hoppema, E. Jeansson, T. Johannessen, V. Kitidis, A. Körtzinger, C. Landa, N. Lefèvre, A. Luchetta, L. Naudts, P.D. Nightingale, A. Omar, S. Pensieri, B. Pfeil, R. Castaño-Primo, G. Rehder, A. Rutgersson, R. Sanders, I. Schewe, G. Siena, I. Skjelvan, T. Soltwedel, S. van Heuven and A. Watson (2019). Constraining the Oceanic Uptake and Fluxes of Greenhouse Gases by Building an Ocean Network of Certified Stations: The Ocean Component of the Integrated Carbon Observation System, ICOS-Oceans. *Front. Mar. Sci. 6:544*, doi: 10.3389/fmars.2019.00544
- Pierrot, D., and T. Steinhoff (2019). Installation of autonomous underway pCO2 instruments onboard ships of opportunity. NOAA Technical Report, OAR-AOML-50, doi:10.25923/ffz6-0x48, 31 pp.
- Hartman, S. E. et al. (2019). Seasonality and spatial heterogeneity of the surface ocean carbonate system in the northwest European continental shelf. Progress in Oceanography 177: 101909.
- Macovei et al. (2019). Temporal variability in the nutrient biogeochemistry of the surface North Atlantic: 15 years of ship of opportunity data. Global Biogeochemical Cycles 33(12), doi: https://doi.org/10.1029/2018GB006132
- Kitidis et al. (2019). Winter weather controls net influx of atmospheric CO₂ on the north-west European shelf. Scientific Reports 9(1) 1-11.
- Tanhua T, Pouliquen S, Hausman J, O'Brien K, Bricher P, de Bruin T, Buck JJH, Burger EF, Carval T, Casey KS, Diggs S, Giorgetti A, Glaves H, Harscoat V, Kinkade D, Muelbert JH, Novellino A, Pfeil B, Pulsifer PL, Van de Putte A, Robinson E, Schaap D, Smirnov A, Smith N, Snowden D, Spears T, Stall S, Tacoma M, Thijsse P, Tronstad S, Vandenberghe T, Wengren M, Wyborn L and Zhao Z (2019). Ocean FAIR Data Services. *Front. Mar. Sci.*6:440. doi: 10.3389/fmars.2019.00440



Central Analytical Laboratories -Central Radiocarbon Laboratory (CAL-CRL)

Highlights

- Scientific Highlight
 - o Successful testing of the ICOS flask sampler
- New funding acquired
 - $\circ~$ Contract for services between CRL-DWD for the investigation of fossil CO_2 sources in the catchment area of the ICOS station Karlsruhe
- Personnel training and development
 - ATC Training Julian Della Colleta
- Events where CRL scientists have been invited as speaker/presenter to represent ICOS
 - o ENVIRA, Prag, I. Levin
 - Public Event "Klimawandelforschung ICOS-D", Freising within the Annual ICOS Germany Meeting, I. Levin
 - o Cape Grim Annual Science Meeting, Aependael, Victoria, Australia, I. Levin
 - 1st ICOS workshop on strategies to monitor greenhouse gases in urban environments, Helsinki / Hyytiälä, Finland, S. Hammer
 - German Meteorological Society (DMG), Advanced training day, Heidelberg, S. Hammer
 - o Teekolloquium, MPI für Kernphysik, Heidelberg, S. Hammer
 - o Geographischen Colloquium, PH, Heidelberg, S. Hammer
- Other attended/hosted meetings
 - o GGMT Conference, Jeju, Korea
 - RINGO annual meeting, Southampton, UK
 - VERIFY annual meeting, Reading, UK
 - o ATM MSA meeting in 2019, Gif-sur-Yvette, France
 - o ATM MSA meeting in 2019, Bologna, Italy
 - o General Assembly Paris, Amsterdam (remotely)
 - o Annual ICOS Germany Network Meeting, Freising, Germany

Radiocarbon analysis of bi-weekly integrated CO₂ samples (Task 1)

In 2019, ten atmospheric ICOS class 1 stations delivered integrated samples to the ICOS CRL. Additionally, we analysed integrated samples from the ICOS class 2 stations Cabauw and Trainou as well as for the ICOS CRL pilot station Heidelberg. Additional samples from the non-ICOS stations Mace Head, and Schauinsland, which serve, together with Jungfraujoch as reference sites to estimate fossil fuel CO₂ concentrations have been analysed. All samples provided from the ICOS atmosphere class 1 network have been analysed (or are in preparation). In total, 354 European samples were analysed by low-level counting. As outlined in the workplan, we used idle measurement capacity for analysing integrated ¹⁴CO₂ samples from the polar stations Neumayer (Antarctica) and Alert (Arctic) as well as from Cape Grim, Toronto and Egbert (the latter two paid by AES, Canada). In total 64 samples from the global network where analysed.

From April 2019 we started to observe an increasing ${}^{14}CO_2$ contamination at Pallas station (PAL). In Pallas, previous ${}^{14}CO_2$ activities (2018-March 2019) did show typical background conditions, varying between 0‰ and 10‰. Between April and September 2019, the ${}^{14}CO_2$ activity rose nearly exponentially



to about 430‰. The sampling was temporally ceased and the station PI is investigating potential contamination sources. PAL station operates an aerosol mass monitor based on beta-absorption (Thermo SHARP) which uses a ¹⁴C source. According to the PI, the rise in the ¹⁴CO₂ activity would be consistent with deteriorating pump diaphragm, which was changed in September 2019. No new ¹⁴CO₂ samples from PAL arrived at the CRL since.

Based on safety concerns at the Lindenberg station (LIN) from the previous years, an additional safety hood with a magnetic shut-off mechanism was constructed for the NaOH sampler. Prototypes are in use. After successful field tests, retrofit kits will be delivered to all ICOS class 1 stations.

In cooperation with the FCL, we created the possibility to enter the metadata of integrated $^{14}CO_2$ samplings directly into the CAL database. Each station PI can register his $^{14}CO_2$ samples via the CAL website.

All level-1 and level-2 results have been transferred to the CAL database in Jena and from there forwarded to the ATC. Therewith, deliverables 1 and 2 were fulfilled.

Personnel task 1: 26.1 PM

Radiocarbon analysis of CO₂ from flask samples (Task 2)

In 2019 the first flasks from the ICOS atmospheric class 1 station network arrived at the CRL and have been processed and analysed. We received 17 samples from KIT and 5 samples from HPB. Other stations have not started sending flask samples for ¹⁴CO₂ analysis.

Thus, as outlined in the work plan, the CRL devoted free flask analysis capacity to develop new sampling strategies and to test new surrogate tracers for regional fossil fuel CO₂ estimation. In total we analysed 156 flask samples from the ICOS CRL pilot station, among other usages these samples have been used to test APO as a potential surrogate tracer for fossil fuel CO₂. More details on this activity will be given in section "other tasks". Within the framework of WP1 of the RINGO project, we analysed 134 flasks from the Paris and the Rhine-valley region. This is less than the 200 flasks which were foreseen in the work plan for deliverable 11. The reduced RINGO flask amount was caused by delayed installation of the RINGO flask samplers in Paris. We will thus carry on analysing RINGO flasks until the end of spring 2020. In total 314 flasks have been processed and analysed.

We continued our efforts to analyse a subset of the integrated ${}^{14}CO_2$ samples also by AMS for quality control purposes. The increasing trend in the difference between AMS and LLC measurements, which was first observed in 2017 and continued in 2018, was also observed in 2019. For 2019 we found a mean AMS-LLC difference of 4.0 \pm 0.3 %. (N=174). The working standard, used to calibrate the LLC measurements, will reach the end of its operating life in 2020 and its nominal activity will be reassigned with respect to the international ${}^{14}C$ scale. In this process, we will also apply measures to account for the drift in the last years.

The quality control measurements carried out at the extraction- and graphitization-line (EGL) were, as well, ongoing in 2019. Based on oxalic acid 1 (SRM 4990 B) measurements, the international ¹⁴C scale could be reproduced to better than 0.06 ± 0.3 % for the AMS measurements. The internal quality control gases show for 2019 a reproducibility (1 σ) between 2.3 and 2.9 %, identical to the performance of 2018.

Level-1 and Level-2 data have been transferred to the station PIs directly. No official flask dataset was released by the ATC yet and the infrastructure for flask data transmission is in the making. Thus, deliverable 3 and 4 have been accomplished by manual data transmission.

Personnel task 2: 21.9 PM



Production of integrated CO₂ samplers (Task 3)

Contrary to the work plan for 2019, one new integrated CO₂ sampler was produced for Cabauw (CBW) station and delivered in November 2019.

Personnel task 3: 0.9 PM

Interaction with station PIs (Task 4)

CRL scientists have participated in person in both atmospheric MSAs, in Gif-sur-Yvette (FR) in spring and Bologna (IT) in autumn 2019 (Deliverable 5&6). All available ¹⁴CO₂ results from integrated sampling had been presented to the participants. There is a regular email exchange between the CRL and the stations, concerning the supply of sampling bottles, spare parts and other issues. The regular transfer of samples to the CRL works smoothly.

Personnel: 2.4 PM

Activities and plan reported to the DG, RI Committee and General Assembly (Task 5)

Reporting of activities and finances in 2018 (Deliverable 7), as well as the work plan and financial plan for 2020 (Deliverable 8), have been submitted to the HO in time. Additional time was devoted to preparing the next 5 years plan and the budget planning. At the GA meeting in Gif-sur-Yvette/Paris (FR) in May 2019, S. Hammer participated and discussed CAL issues with the GA. S. Hammer, was also connected remotely to the GA in Amsterdam and participated at the RI COM face-to-face meeting in Düberndorf (CH) in September 2019. With very few exceptions, either I. Levin or S. Hammer or both have participated at the regular monthly teleconferences of the RI COM.

Personnel: 3.6 PM

State other activities that are additional to those stated above

In 2019, the CRL has operated the ICOS CRL pilot station which includes:

- continuous in-situ measurements with ICOS-compliant CRDS and FTIR analysers
- continuous in-situ O_2/N_2 measurements to monitor atmospheric potential oxygen (APO), as a new potential surrogate tracer for fossil fuel CO_2
- semi-continuous in-situ ²²²Rn measurements
- flask sampling using the ICOS flask sampler
- integrated CO₂ sampling for ¹⁴CO₂ analysis

With the continuous operation and the transmission of the in-situ data to the ATC deliverable 9 was accomplished.

One major task of the CRL pilot station in 2019 was to assess the capability of the ICOS flask sampler for independent, end-to-end quality control of in-situ measurements. For this purpose, 141 flasks were filled at the pilot station and analysed at the FCL in Jena concerning their GHG concentration.

The comparison to the in-situ measurements demonstrated that for situations with low variability of ambient air concentrations a very good agreement, below the WMO compatibility targets, could be achieved. Thus, we can approve that the ICOS flask sampler is well suited for the quality control of continuous in-situ measurements.



In the course of the RINGO project, an ICOS flask sampling strategy was developed under the supervision of I. Levin, and was presented several times at the atmospheric MSAs and is currently being published.

Personnel expenditures for operating the pilot station and validation of the flask sampler: 9.8 PM

A second major task of the CRL pilot station was to investigate the potential of atmospheric potential oxygen (APO) as a tracer for fossil fuel CO₂. Since precise atmospheric APO measurements are very demanding the CRL is collaborating for this topic with the group of Andrew Manning at UEA, Norwich, UK which are experts for APO measurements. Penelope Pickers is specially hired on a 50% position for this project.

APO, a tracer derived from atmospheric O_2/N_2 and CO_2 measurements, has been measured continuously at the CRL pilot station since November 2018. The O_2/N_2 data are reported on the Scripps Institution of Oceanography O_2 scale and the CO_2 data are linked to the WMO CO_2 scale, via cross-referencing to the available calibration cylinders from the FCL. The O_2 and CO_2 measurement system performance is generally good. The CO_2 measurement usually meets WMO repeatability and compatibility recommendations, however, there are periods when the CO_2 baseline drift is significant, owing to changes in the laboratory temperature which affect the temperature-sensitive Siemens NDIR CO_2 analyser. The O_2 measurements meet the extended WMO repeatability and compatibility recommendations and are comparable to other O_2 measurements made using a Sable Systems 'Oxzilla' O_2 analyser. We account for all measurement-related uncertainties in our APO-based ffCO₂ estimates and exclude periods of data when we deem the CO_2 baseline drift to be significantly large. The total data loss from our continuous APO data amounts to just under 20% for the year Nov2018-Oct2019 (i.e. we have continuous data coverage for just over 80% of the time). Most of this data loss occurs when the measurement system is calibrating or running a quality control cylinders and is therefore unavoidable.

The value of using APO as a tracer for fossil fuel CO_2 (ff CO_2) is being tested by comparing the APOderived ff CO_2 estimates to those from other existing atmospheric measurements at the pilot station, in particular ¹⁴ CO_2 . From November 2018 until October 2019, 112 'event' flasks have been measured and analysed for ¹⁴ CO_2 , for which we have corresponding quality-controlled APO data for the comparison. The APO-based ff CO_2 agrees well to ¹⁴ CO_2 -based ff CO_2 estimates in terms of timing and, to first order, in the amplitude of the signal; however, there are sometimes significant differences.

Owing to the heterogeneity of local sources within the Heidelberg footprint, we find that the APO:ffCO₂ ratios are significantly more variable than the corresponding ratios from an emissions database product called COFFEE. This is not surprising since COFFEE has relatively coarse spatial resolution and emissions in the Heidelberg footprint come from heterogeneous sources.

We are currently investigating if patterns of APO:ffCO₂ ratios are corresponding to different atmospheric transport parameters, such as measured meteorological data, radon data and modelled atmospheric footprints, to see if APO can be used as an independent $ffCO_2$ tracer, or whether it will require regular 'calibration' using ¹⁴CO₂ measurements. A presentation on the APO measurements at the ICOS CRL pilot station was given by Penelope Pickers at the MSA in Bologna, fulfilling thereby deliverable 10.

Personnel expenditures: 8.4 PM

Other publications in 2019

• Ries, C. (2019). Setup and first results of a two-station based monitoring of urban fossil fuel emissions in the upper Rhine valley and the Paris metropolitan area (Master thesis)



Central Analytical Laboratories - Flask and Calibration Laboratory (CAL-FCL)

Highlights

- Scientific Highlight:
 - Start of implementation of flask sampling strategy using the ICOS flask sampler.
- Funding:
 - $_{\odot}$ Successful negotiation of CAL host funding increase for the next 5 year period with support from the DWD
- Public Events
 - ICOS Scapes photo exhibition, Jena (24.-31.06.2019)
 - public talk by Armin Jordan on ICOS at the Thüringer Klimapavillon, Jena (27.06.2019)
 - Jena "Long Night of Science" on 24.11.2019, talks by Markus Eritt and Armin Jordan and laboratory tours
 - Interview by public news broadcast (MDR Mitteldeutscher Rundfunk) with Armin Jordan on 02.12.2019 (start of COP25)
- Attended meetings
 - o RINGO annual meeting, Southampton, UK, March 2019 (Markus Eritt)
 - GGMT Conference, Jeju, Korea (Markus Eritt, Armin Jordan)
- *New recruit*: Olaf Till could be hired end of 2019 to succeed Stephan Braune as ICOS CAL database developer

Trace gas analysis (CO₂, CH₄, CO, N₂O, SF₆, H₂) of flask samples (Task 1)

In May 2019 the ICOS flask sampling strategy has been adopted at the MSA and first flask samples collected at ICOS stations using ICOS flask sampling equipment were provided for analysis to the FCL (DE-HPB, DE-KIT and SE-NOR) and two additional stations operating pre-ICOS equipment (FR-OPE and DE-SIL). All samples have been analysed by gas chromatography (Deliverable 1). While the number of atmospheric samples increases the main activity has remained in supporting tests to establish the ICOS flask sampling program. A malfunction of the Electron Capture Detector impacting specifically the SF₆ analysis has required extensive troubleshooting experiments that have not concluded yet.

Analysis of supplement parameters (CO $_2$ stable isotopes and O $_2/N_2$ ratios) (Task 2)

As envisaged in the 2019 work plan the focus of Task 2 activities was to ensure the availability of proper sampling equipment to be distributed in the atmospheric network and such enable the implementation of the ICOS flask sampling strategy that was elaborated by the CRL together with the Carbon Portal within RINGO (adopted at the MSA in May 2019). The main efforts and results in 2019 were:

- Finalization and upgrade of the software operating the flask samplers and driers to be fit for various tasks flask sampling strategy. New developments comprise
 - programmable dynamic flow filling schemes for time integrated sampling
 - the option of an automated communication of the sampler with the ATC and CRL after sample collection. This shall allow an automated decision whether to maintain the sample or re-sample the flask later based on the suitability of the atmospheric conditions during sampling for fossil fuel CO₂ detection (Milestone 1)



- Hardware upgrades of samplers that have been delivered already for dynamic flow sampling (Milestone 2)
- Additional two class 1 stations have been equipped with flask samplers. 15 stations have received a flask sampler by end of 2019.
- Intensive tests of these design upgrades in a dynamic flow sampling scheme were successfully performed in collaboration with the CRL and further on this sampling has been implemented at ICOS stations

Flask samples have been analysed for CO_2 stable isotopes (Deliverable 2). The O_2/N_2 measurement program has been considerably delayed due to the long-term illness of the engineer associated to this task (absent throughout the entire year).

Production of real air high pressure standard gases (CO₂, CH₄, CO) (Task 3)

With the provision of standard gases to Station Nord all nominated ICOS atmospheric stations have now been equipped with reference standards to allow their rapid labelling (Deliverable 3). Highly consumed standard gases that have been exhausted at the stations have been replaced. Additional standard gases are regularly needed for the FCL, CRL and ATC operations, and the ICOS internal and external quality control (QC) activities. A total of 117 real air standard gases in high pressure cylinders has been produced in 2019.

Calibration and re-calibration of standard gases (Task 4)

All standard gases produced in task 3 have been calibrated (Deliverable 4).

The WMO Central Calibration Laboratory (CCL) is still finalizing the CO₂ scale revision so Milestone 3 (reprocessing of CO₂ measurement results) is postponed to when the new CO₂ scale is available. For CO, re-calibration results by the CCL of all FCL primary standard gases showed significant drifts in the assignments of CO that had been suspected based on QC activities. A reprocessing of all CO data has been made based on trend functions in the assigned CO values of the FCL references to minimize the associated error of drifting references on the FCL CO measurement results. This has been completed in summer 2019 and submitted to the ATC for reprocessing of the atmospheric continuous data.

Six Replacement Sets are available for periods when stations return their standard gases for recalibration. In 2019 this has been used by the stations FR-OPE, NO-ZEP and DE-LIN (Deliverable 5)

Organisation of and participation in international QC activities (Task 5)

The activities in the international QC programs ("Sausage" - Flasks and "MENI" – **M**PI-**E**MPA-**N**OAA-**I**COS) have been continued. The FCL contributes one set of comparison standards for the upcoming WMO Round Robin that includes hydrogen measuring laboratories (Deliverable 6).

The QC report was updated considering the results from all internal and external QC activities conducted in 2019 (Deliverable 7).

Activities and plan reported to the DG, RI Com and General Assembly (Task 6)

The general report (Deliverable 8) including the financial and activity report 2018 has been submitted to the HO in Feb 2019, the budget and work plan for 2020 were provided in October 2019. Additional



time was devoted to contribute to the preparation of the next 5 years financial and action plan and the ICOS strategy document. Updates on FCL activities were also presented at the General Assemblies and an FCL representative was participating at the General Assembly in November 2019.

Interaction with station PIs (Task 7)

The FCL scientists participated at the ICOS Atmosphere MSA in Saclay and Bologna in May and November 2019, respectively. The reports on FCL activities were put up for discussion and the revision of CO data resulting from reference gas reassignments was explained. A flask sampler user feedback session was organized in Bologna. Daily communication of specific topics (e.g. reference gases, flask samples, flask sampler) between individual station PIs, other central facilities and FCL is facilitated by dedicated mailing lists and named contact persons (Deliverable 9).

Other publications in 2019

Poster presentations at the 20th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases, and Related Measurement Techniques:

- M. Eritt: The ICOS automated flask sampler
- Jordan, D. Rzesanke: Uncertainty analysis of calibration measurements made by the ICOS Flask and Calibration Laboratory



Monitoring Station Assemblies (MSAs)

Atmosphere MSA

Scientific Highlights from 2019

• CO₂ and CH₄ time series from atmospheric ICOS stations are provided in near real-time to the Copernicus Atmospheric Monitoring Service for model evaluation.

Important milestones and highlights in 2019

- Two MSA atmosphere meetings were held in 2019. One was in Gif-sur-Yvette, France, May 14-16 and the other one in Bologna, Italy, November 18-20, respectively.
- In November 2019, Martin Steinbacher from Switzerland and Paolo Cristofanelli from Italy were elected as MSA atmosphere chair and substitute chair, respectively.
- The second level2 data of 19 atmospheric stations (49 vertical levels) were released in August 2019, https://doi.org/10.18160/CE2R-CC91.
- Seven atmospheric stations were approved as labelled ICOS stations.
- A publication was prepared documenting the impact of the widespread drought over Northern and Central Europe in summer 2018 on the atmospheric carbon dioxide concentrations; data from 48 stations were analysed, the majority of them were ICOS stations; the publication is currently under review in Philosophical Transactions B.
- Documentation of operational procedures is continuously elaborated (like the operation and calibration procedures of dual-flow-loop two-filter radon detectors or best strategies for selecting suitable flasks for ¹⁴C analysis) and shortcomings in the communication with respect to shipping and analysis of flasks after sampling were identified and fixed.

Ecosystem MSA

Important milestones and highlights in 2019

- Survey within station teams on problems and issues during labelling phase and during operation
- Feedback of survey to ETC
- MSA meeting in Marseille, May 2019, survey as main topics

Significant publications or other material in 2019

• Several contributions to drought 2018 analysis special issue

Ocean MSA

1-3 Scientific Highlights from 2019

- ICOS OTC North Atlantic Carbon Symposium (19th March 2019, NOC, UK). Most of Ocean MSA Pls attended and presented in the Symposium.
- Participations of many stations in the OTC sensors workshop in Kiel (October 2019). Pls met with suppliers of pCO₂ sensors and systems as well as with colleagues from non ICOS stations
- Participation of ICOS Ocean PIs in OceanObs 2019 conference, Hawai
- Joint inter-comparison activity between NOC, VLIZ and PML during the PAP cruise DY103 (June-July 2019)



• Saildrone Mission Atl2Med (https://www.saildrone.com/mission/atl2med), organised by ICOS OTC, will serve for the verification of a nr of ICOS Ocean FOS stations (started in Sep 2019 and activity will be completed in 2020)

Important milestones and highlights in 2019

- Ocean MSA meeting was held in March 18th 2019 in NOC, UK, just before the RINGO Annual meeting.
- Tobias Steinhoff (GEOMAR, DE) stepped down as chair of the MSA (March 2019). Thanos Gkritzalis (VLIZ, BE) continuous as chair and Sue Hartman (NOC, UK) was elected co-chair
- 2nd MSA of the year was held in Kiel GEOMAR on 27-28 November, 2019
- In the Nov 2019 GA (Helsinki), the GA approved the support of CAL to the Ocean stations with the provision of high-quality standard gases. The scheme is expected to start in 2020.

Significant publications or other material in 2019

- Steinhoff, T. *et al.* (2019) 'Constraining the Oceanic Uptake and Fluxes of Greenhouse Gases by Building an Ocean Network of Certified Stations: The Ocean Component of the Integrated Carbon Observation System, ICOS-Oceans', *Frontiers in Marine Science*, 6(September), pp. 1–15. doi: 10.3389/fmars.2019.00544.
- Kitidis, V. *et al.* (2019) 'Winter weather controls net influx of atmospheric CO2 on the north-west European shelf', *Scientific Reports*, 9(1), pp. 1–11. doi: 10.1038/s41598-019-56363-5.
- Macovei, V. A. *et al.* (2020) 'Impact of physical and biological processes on temporal variations of the ocean carbon sink in the mid-latitude North Atlantic (2002–2016)', *Progress in Oceanography*. Elsevier, 180(April 2019), p. 102223. doi: 10.1016/j.pocean.2019.102223.
- Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., *et al.* 2019. Global Carbon Budget 2019, Earth Syst. Sci. Data, 11, 1783–1838, https://doi.org/10.5194/essd-11-1783-2019.



ICOS National Networks' Highlights

ICOS Belgium

Highlights

Networking success

- Representation of ICOS Wallonia (ICOS-WB) within the internal structure of the faculty. Two of our stations have been officially integrated into a CARE (Centre d'Appui à la Recherche et à l'Enseignement), an official component of the research infrastructure of the University of Liège.
- Cross-Border Mixed Research Unit, TERRA-VIOLLETTE, International Research Center in Biological Engineering applied to Agriculture, Agri-Food and Biotechnology: project submitted by ICOS-WB. The project includes the ICOS-France Estrée-mons station, which will allow to work more closely with another ICOS team.
- Kick-off of the step 2 of the labelling procedure for the Dorinne ecosystem station.
- The Brasschaat ecosystem station was chosen as test site for new soil flux chambers developed by Eosense and Picarro. The chambers were installed in May 2019.

New recruits/appointments

- On 01 October 2019, Belgian focal point Prof. dr. Reinhart Ceulemans (University of Antwerp) retired as an emeritus professor after an impressive and fruitful career. As of that date, Prof. dr. Ivan Janssens (UAntwerp) took over the role of Belgian focal point.
- Jasper Van Look, an industrial engineer was hired as technician (1 July 2019 30 June 2020) to strengthen the ecosystem station team at UAntwerp operating the three Flemish ecosystem stations.
- March 2019, Thanos Gkritzalis (VLIZ) was elected chair of the oceans MSA.
- Louis Gourlez de la Motte (post-doctoral researcher) was hired from 01 October 2019 to 31 January 2020 and Ariane Faurès (engineer) was hired on 04 November 2019 by the University of Liege for one year to help in the management of the Walloon ecosystem stations and in the data processing.

Domain specific training/workshops/meetings

- On 30 August 2019 a training was held at the University of Antwerp for operating laser gas analysers for CH4 and N2O.
- February 2019, Dr. T. Steinhoff, an OTC engineer, visited VLIZ to get more information on the two ocean stations and provide technical support for the RV Simon Stevin (ICOS Station under labelling evaluation)
- ICOS-Monitoring System Assembly (MSA) meeting in Marseille from 22 -24 May 2019: Presentations and discussions on the labelling process and on the ETC activities. Attended by both UAntwerp and ULG-UCL team members.
- ICOS ECO France technical days at Bordeaux from 25 to 26 June 2019. Attended by ICOS-WB members with presentations of the Walloon ICOS stations and the soil samplings carried out.

Participation to projects

• Participation in the 2018 Task Force on Drought: special issue in the journal "Philosophical Transactions of the Royal Society". Ecosystem stations Vielsalm and Lonzée are involved in a study on the role of non-stomatal and stomatal processes on the assimilation of carbon by forests, carried out by Louis Gourlez de la Motte. Dr. Bert Gielen (ETC) and dr. Marilyn Roland



(PI Maasmechelen ecosystem station) attended the face-to-face meeting in Amsterdam on 22 February 2019.

- The soil carbon data from three ecosystem stations (Brasschaat, Lochristi, Maasmechelen) are being used in a Flemish study on soil carbon mapping by BOS+ (<u>https://www.bosplus.be/en/</u>).
- BIRA-IASB co-authored a concept document for the European Total Carbon Column Observing Network (TCCON) integration into ICOS. This document was part of the RINGO project and accepted by the ICOS head office.
- CEOS/WGCV/LPV initiative: the Lonzée ecosystem station is a proposed "super site" for the validation of terrestrial products. (<u>https://lpvs.gsfc.nasa.gov/</u>). Support for spectrometer measurements and hemispherical photography in a 3 x 3 km² area around the tower.
- Commission for Agricultural Meteorology (WMO): the Lonzée and Dorinne ecosystem stations have been included in the list of instrumented sites for turbulent flow measurements (energy, H2O, CO2 and other greenhouse gases) on agricultural area such as crops or pastures.
- Forest Flow (BELSPO): Estimation of dissolved organic compounds flows at the scale of the plot and the watershed (UA, KUL, UCL, IRM). Vielsalm and Brasschaat ecosystem stations are studied.
- BELAIR (Sylva): Study of the spatial and temporal variability of indicators related to forest cover (NDVI, PRI, LAI, PAR) on the BELAIR SILVA site by terrestrial measurements coupled with BELAIR measurements (APEX flights and drones in July 2018). The Vielsalm station is involved with a data report submitted.
- NEC (Agence wallonne de l'air et du climat): Assess the impact of atmospheric pollution on ecosystems / habitats (acidification, eutrophication, ozone damages). The Vielsalm station is involved. A Belgian template was submitted to the European Commission.
- KIC Project (INRA Laon et Montpellier, ZALF, CYBELTECH): Controlling barley fertilization by assimilating UAV data into crop models: database exchange between partners.
- STRENGTHENING PRIORITY FSI COMPONENTS INTO KEY ESFRI RESEARCH INFRASTRUCTURES: Aerosols, clouds and trace gazes European research Infrastructure - Actris RI (ESFRI road map 2016) with Belgian partners BIRA, KMI, IsseP, Ulg. A PTR-(TOF)-MS and a MAX-DOAS (Airyx SkySpec system) will be installed at the ecosystem station of Vielsalm in 2020. Implementation is planned for 2024.
- Dendrochronology (F. Bast): analyses of wood cores taken at Vielsalm are now available.
- ACRVF (DGO3, SPW): Assessment of water stress in the soils of the Walloon forest: best estimate of extractable water.
- BERTRAC (BELSPO, FED-tWIN): Investigation of bidirectional surface/atmosphere exchange of reactive trace compounds in terrestrial ecosystems through measurements and modelling. Example of synergy with ISSEP through ACTRIS.

Organised events to promote ICOS

• University of Antwerp, University of Liege and Royal Belgian Institute for Space Aeronomy organised the 2019 ICOS Belgium Science Conference, on 3 October 2019 in Antwerp. With speakers from ACTRIS, Copernicus, AnaEE, Terrascope, Citizen science project Knappe K(n)oppen and Tech company ABB and more than 65 participants.

Attended events to promote ICOS

- Dr. Bert Gielen attended the LifeWatch.be Users & Stakeholders Meeting on 19 November 2019 in Brussels.
- Dr. Marilyn Roland and dr. Bert Gielen represented ICOS in the annual LTER Belgium meeting on 14 January 2019.
- Thi Minh Tu Nguyen (FP assistant) attended the ENVRIPlus Final Dissemination event: Collaboration for the impactful Earth System science on 04 June 2019 in Brussels.



Organised/attended campaigns to promote ICOS

- Prof. Ivan Janssens (focal point, PI of the Brasschaat ecosystem station) was one of the lead authors of an Open Letter for a more ambitious climate policy. The Open Letter was initiated by the Global Change Ecology Centre (GCE) of UAntwerp. The letter summarises the main facts about climate change in seven clear statements and was a reaction in support of the school strikes by Youth4Climate. 3400 academics signed the letter, demonstrating the broad scientific consensus on both the drivers of climate change and the action required to limit the rise in temperatures below the 1.5 °C target. The Open Letter was cited on the Instagram accounts of the Guardian and Leonardo Dicaprio.
- Contribution by Thi Minh Tu Nguyen to the "National Initiatives" survey by EOSC-Pillar. The aim of this survey is to analyse the current national and thematic initiatives on open research data and services that may contribute to the implementation of the European Open Science Cloud EOSC.
- UAntwerp contributed to the Flemish ESFRI brochure that will be published by the Research Foundation Flanders (FWO).
- On 3 April 2019 a group of students of the University of Liège came to visit the Brasschaat ecosystem station. This excursion was supervised by dr. Bert Gielen.
- On 24 September 2019 a group of students of the University of Ghent came to visit the Lochristi ecosystem station. This excursion was led by dr. Marilyn Roland.
- The university of Antwerp organised a workshop for secondary school students at the Brasschaat ecosystem station 0n 18 and 23 October 2019. This workshop was part of the citizen science project Knappe K(n)oppen.
- 24 November 2019, dr. Dre Cattrysse (VLIZ) presented ICOS activities during the Belgian Science Day (<u>https://www.dagvandewetenschap.be</u>; outreach)
- BIRA-IASB has an active Twitter account for the atmospheric station RUN on Réunion island.
- Federal Public Service public health, food chain safety and environment Climate change: training in primary, secondary and higher education. Project in progress.
- Presentation of the Lonzée ecosystem station to students in the frame of Vivasciences on 19 December 2019 in Lonzée.
- Presentation of the Dorinne station during the visit of the European deputy Philippe Lamberts on 03 May 2019 by prof. Bernard Heinesch (PI Lonzée and Dorinne ecosystem stations) in the context of greenhouse gases in agriculture.

Events attended as invited speaker/presenter to represent ICOS

- Prof. Ivan Janssens (FP and PI BE-Bra) and prof. Reinhart Ceulemans (former FP and PI BE-Lcr) presented ICOS at the 'Connecting ESFRIs in Flanders' kick-off meeting on 5 June 2019 organised by the Flemish department of Economy, Science and Innovation (EWI) in Brussels.
- Prof. Ivan Janssens and Thi Minh Tu Nguyen attended the "Connecting ESFRIs in Flanders' follow up meeting organised by Elixir and Lifewatch. The goal was to get an overview of the activities and priorities of the ESFRI's in Flanders related to data.
- Dr. Marilyn Roland, was invited to present the Maasmechelen ecosystem station at the UHasselt Field Research Center research information meeting in Hasselt on 14 December 2019.
- Presentation at the Agricultural Committee of Virton on 19 February 2019 in Virton by prof. Bernard Heinesch. Subject of the presentation: "Climate Change and Agriculture".
- Presentation during the Agriculture and Air Quality Symposium on 21-22 March 2019 at INRA Paris by prof. Bernard Heinesch: the exchanges of Volatile Organic Compounds between agrosystems and the atmosphere.
- Oral presentation at the annual congress of the Royal Society of Sciences of Liège by prof. Bernard Heinesch and prof. Bernard Longdoz on 29 November 2019: Current and Future Impact of Terrestrial Ecosystems on our Climate.



Major meetings within the National Network

• Fifth ICOS Belgium annual meeting on 20 June 2019 organised in Lochristi for the Belgium consortium. The meeting included a field trip to the Ecosystem Station of Lochristi.

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

- January 2020, general ICOS poster for FWO IRI call information and networking event by dr. Marilyn Roland and Thi Minh Tu Nguyen.
- January 2020, ICOS Flanders poster for FWO IRI call information and networking event session by Thi Minh Tu Nguyen.
- February 2019, new ICOS Belgium and ICOS Flanders brochures by Thi Minh Tu Nguyen.
- Thanos Gkritzalis; Carbonate chemistry and carbon fluxes in the Belgian coast and South North Sea; Oral presentation at 2019 ICOS Belgium Science Conference on 3 October in Antwerp:
- Mahesh Kumar Sha, Nicolas Kumps, Christian Hermans, Minqiang Zhou, Bavo Langerock, Francis Scolas, Corinne Vigouroux, Bart Dils, Jean-Marc Metzger, Jean-Pierre Cammas, Michel Ramonet, Lea Gest, Marc Delmotte, Martine De Mazière; Belgian ICOS atmospheric station at Reunion Island – a joint collaboration between BIRA-IASB, LACy/OSU-R and LSCE/IPSL; Poster presentation at the 2019 ICOS Belgium Science Conference, 3 October 2019, Antwerp.
- Mahesh Kumar Sha, Nicolas Kumps, Christian Hermans, Minqiang Zhou, Bavo Langerock, Francis Scolas, Corinne Vigouroux, Bart Dils, Jean-Marc Metzger, Jean-Pierre Cammas, Michel Ramonet, Lea Gest, Marc Delmotte, Martine De Mazière; Site Report: BIRA-IASB: Maido; Oral presentation at the 2019 Joint NDACC-IRWG and TCCON meeting; 20 – 24 May 2019, Wanaka, New Zealand.
- Louis Gourlez de la Motte; Quantification of 2018 drought for European terrestrial ecosystem plots and impact on stomatal and nonstomatal limitation of photosynthesis and evapotranspiration. Oral presentation at the 2019 ICOS Belgium Science Conference, 3 October 2019, Antwerp.
- Q. Beauclaire et al; Impact of the 2018 drought on the CO₂ and H2O exchanges of a potato crop (Solanum tuberosum L.); Poster presentation at the 2019 ICOS Belgium Science Conference, 03 October 2019, Antwerp.
- F. Boland et al; Multiyear analysis of energy balance closure over a cropland at a Belgian ICOS flux-tower station; Poster presentation at the 2019 ICOS Belgium Science Conference, 3 October 2019, Antwerp.
- N. De Cock et al; Effect of point source emission height on the error of the flux estimation through eddy covariance; Poster presentation at the 2019 ICOS Belgium Science Conference, 03 October 2019, Antwerp.
- L. Delhez; TADA, a mechanistic model for carbon, nitrogen and water cycle in cropland and grassland ecosystems; Poster presentation at the 2019 ICOS Belgium Science Conference, 3 October 2019, Antwerp.
- L. Gourlez de la Motte; Herd position habits can bias net CO2 ecosystem exchange estimates in free range grazed pastures; Oral presentation at EGU 2019, Vienna.
- Dumortier P., De Cock N., Aubinet, M., Lebeau, F., Naiken, A., Heinesch, B., Lognoul M. et al; Point source emission estimation using eddy covariance: Validation using an artificial source experiment; Poster presentation at EGU 2019, Vienna.



- Lognoul, M., Gourlez de la Motte, L., Naiken, A., Lonneux M., Segers J., Arriga N., Roland, M., Beckers Y., Bodson, B., Heinesch, B., Aubinet, M. Restoring a worn-out pasture: what impact on N2O exchanges? Poster presentation at EGU 2019, Vienna.
- Gaia P. et al; First results from the KinAero MAXDOAS; Poster presentation at EGU 2019, Vienna.
- An online visualization tool was developed by ULG-UCL. This tool should provide an elaborate and easily accessible (on the national website) graphical representation of the data acquired at the stations. It will be used both for quality control measurements by the ICOS team, to inform the scientists using the station data and for internal communication within our institutions and external communication to a wider public.
- Gourlez de la Motte, L., La chasse au carbone est ouverte, Dossier climat Pleinchamp, publication of the FWA, n° 15, 11 april 2019
- Lognoul, M., Symphonies en sols agricoles majeurs, Dossier climat Pleinchamp, publication of the FWA, n° 15, 11 april 2019
- Heinesch, B., Longdoz, B., Current and Future Impact of Terrestrial Ecosystems on our Climate, Newsletter of the Royal Society of Sciences of Liège, vol 88, 29 November 2019
- B. Heinesch; Présentation of ICOS on 27 June 2019 at Liège, Pecha Kucha, organized by the asbl Gotoro (<u>https://www.pechakucha.com/presentations/vachement-polluant</u>)

List of labelled stations in 2019

• Observatoire de l'Atmosphère du Maïdo – ICOS Class2 Atmosphere Station – PI : Martine De Mazière ; station acronyme : RUN

1-3 Scientific Highlights from 2019

- Data from the Brasschaat ecosystem station were used as Ground-Based Observations for Validation (GBOV) of Copernicus Global Land Products. This resulted in a manuscript that is currently under review in the journal 'Remote Sensing'.
- Active participation in the 2018 Task Force on Drought which is preparing a special issue on the subject in the scientific journal "Philosophical Transactions of the Royal Society". An article was submitted in early January 2020 within this special issue by Louis Gourlez de la Motte (UCL), titled "Non-stomatal processes reduce gross primary productivity in forest ecosystems during edaphic drought". This study, which compiles the measurements of 10 European forest sites including the Vielsalm ecosystem stations, is emblematic of the usefulness of the network of flux towers to provide rapid responses to major climatic events on a continental scale.



ICOS Czech Republic

Highlights

• Opening of CzechGlobe- Tropical GHG station in Vietnam following some of the ICOS protocols

National ICOS scientists in media:

• Prof. Marek in the main Czech TV talk show Otázky Václava Moravce 17. 3. 2019 https://www.ceskatelevize.cz/porady/1126672097-otazky-vaclava-moravce/219411030510317otazky-vaclava-moravce-2-cast/

International conferences and workshops:

- 11th Earsel Imaging Spetroscopy, Number of participants: 200 of which foreign: 105 (Brno, 5. 8.2.2019)
- DriDanube MEETING, Number of participants: 25 of which foreign: 18 (Brno, 24.–25.1.2019)
- Meeting for the DryPan project: Novel EO data for improved agricultural drought impact forecasting in the Pannonian basin, Number of participants: 11 of which foreign: 7 (Brno, 3.12.2019)

National conferences and workshops:

• Extremes of weather and climate change: context or chance? Number of participants: 20 (Brno, 21.11.2019)

Seminars and meetings:

- Scientific lecture within the Week of Science and Technology Michal V. Marek: Global Change Attacks Myth or Reality in the Light of the Encyclical of Pope František "LAUDATO SI", Number of participants: 60 (Brno, 13.11.2019)
- Scientific Lecture within the Week of Science and Technology Alexander Ač: Global Climate Change as an Environmental Challenge of the 21st Century, Number of Participants: 50 of which from abroad: 1 (Brno, 13.11.2019)
- Scientific Lecture within the Week of Science and Technology, Jiří Jakubínský: Global climate change and its local impacts (not only) on human society, Number of participants: 40 (Brno, 13.11.2019)
- Professional excursion at the Experimental Workplace Bílý Kříž, Number of participants: 79 (Bílý Kříž, 24.10.2019)
- Scientific seminar, Sibu Simon CEITEC, Number of participants: 20 of which from abroad: 2 (Brno, 11.3.2019)
- Lecture within the presentation of LRI at the Academia bookshop in Brno: Dr. Marian Pavelka -Biological carbon pump and its influence on climate change, Number of participants: 15 (18.9.2019)
- Lecture within the presentation of LRI at the Academia bookshop in Brno: prof. Petr Horáček -Will Spruce Survive the Year 2020 or Does the Spruce Have a Chance to Cope with Climate Change? Number of Participants: 15 (14.10.2019)
- RINGO summer school was held in Brno (16 20 September). It was addressed to ICOS candidate countries and focused at technical requirements related to the research infrastructure establishment and operation. Theme was showcase on CzechGlobe research infrastructure and its ICOS ecosystem and atmospheric stations. Six participants from three countries attended lectures and also received hands-on training directly at the ICOS stations.



Experts of ICOS CZ make infrastructure visible and its use in all types of media (Czech National Television and Radio programmes and channels: Studio6 CT24, Studio CT24, Ninety CT24, Horizon, VM questions, VM focus, Czech Radio Plus, Leonardo magazine, printed media, internet news). The most interesting outputs are archived and can be found on the CzechGlobe website http://www.czechglobe.cz/cs/category/czechglobe-v-mediich/

- European Researchers' Night at ICOS CZ station CZ BK1 (Bily Križ Forest), 27.9.2019.
- In Prague, in the premises of the Chamber of Deputies of the Parliament of the Czech Republic, the first annual conference "Water-Drought" was held under the auspices of the Agricultural Committee of the Chamber of Deputies of the Parliament of the Czech Republic.
- On March 23, 2019, an Open-Door Day organized at the Atmospheric Station in Kresin. This event organized on the occasions of World Water Day (22 March) and World Meteorological Day (23 March). Number of visitors: approx. 120.
- On January 24, ACTRIS Transnational Access (TNA) activities brought a group of researchers from France to the Atmospheric Station infrastructure.

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

• On-line training materials about ICOS infrastructure management, construction, operation published in RINGO project EMDESK websites.

Video/article on the web

- <u>https://www.ceskenoviny.cz/zpravy/intersucho-vice-nez-tretina-uzemi-cr-trpi-suchem-v-pude-do-100-cm/1837444</u>
- <u>https://ekolist.cz/cz/zpravodajstvi/zpravy/sef-czechglobe-povazuje-zemanuv-projev-za-neprijatelny-a-tragicky</u>
- <u>https://archiv.ihned.cz/c1-66695280-chybi-nam-popularizatori-vedy-proto-to-dulezite-krici-greta</u>
- <u>https://www.ceskenoviny.cz/zpravy/i-pres-vlhky-listopad-zustava-hlavne-jih-cech-postizeny-suchem/1826294</u>
- <u>https://www.ceskatelevize.cz/porady/10253214196-zpravy-v-16/219411016001125/</u>
- <u>https://plus.rozhlas.cz/jak-se-lisi-zarostla-louka-zelena-strecha-nebo-par-stromu-uprostred-mesta-8082635</u>
- <u>https://www.ceskenoviny.cz/zpravy/sucho-v-pude-uz-zustava-prevazne-jen-v-libereckem-kraji/1798387</u>
- <u>https://www.ceskenoviny.cz/zpravy/zemedelske-sucho-trapi-nejvice-sever-a-severozapad-cech/1793351</u>
- <u>https://zpravy.aktualne.cz/domaci/povrchove-sucho-ustupuje-podivejte-se-kde-jeste-situace-zust/r~b7c51af0c28811e9b7740cc47ab5f122/</u>
- <u>https://www.ceskenoviny.cz/zpravy/zemedelske-sucho-z-ceska-po-destich-zatim-pomalu-ustupuje/1784265</u>
- <u>https://www.ceskatelevize.cz/porady/11412378947-90-ct24/219411058130723/</u>



- <u>https://www.ceskenoviny.cz/zpravy/sucho-se-v-minulem-tydnu-v-cr-rozsirilo-situace-se-zhorsi/1779824</u>
- <u>https://www.ceskenoviny.cz/zpravy/sucho-z-ceska-mirne-ustoupilo-ztraty-na-urode-jsou-velke/1777718</u>
- <u>https://www.ceskenoviny.cz/zpravy/extremni-sucho-je-na-polovine-uzemi-republiky-bude-se-sirit/17755654</u>
- https://archiv.ihned.cz/c1-66600790-vlna-veder-je-ukazkou-jak-cesko-postihne-zmena-klimatu
- <u>https://domaci.ihned.cz/c1-66591500-do-ceska-se-po-destivem-kvetnu-vraci-sucho-projevuje-</u> <u>se-na-dvou-tretinach-uzemihttps://www.novinky.cz/domaci/clanek/prsi-ale-porad-malo-</u> <u>40284894</u>
- <u>https://ct24.ceskatelevize.cz/domaci/2823674-kvetnove-deste-zmirnily-sucho-skody-na-polich-ale-spravily-jen-castecne</u>
- <u>https://www.ceskenoviny.cz/zpravy/intersucho-deset-procent-uzemi-cr-nadale-trpi-extremnim-suchem/1758201</u>
- <u>https://ct24.ceskatelevize.cz/veda/2819897-klimaticka-zmena-narusuje-internet-stromu-muze-zmenit-jejich-fungovani-varuji-vedci</u>
- <u>https://www.ceskenoviny.cz/zpravy/zemedelci-jsou-stale-pesimistictejsi-sucho-se-stupnuje/1748207</u>
- https://media.monitora.cz/pdf-preview/3212/60834511-a71a1f923c6bc418bcbb/
- https://www.ceskatelevize.cz/ivysilani/10314156487-uchem-jehly/219562216200003
- <u>https://www.ceskatelevize.cz/porady/1126672097-otazky-vaclava-moravce/219411030510317-otazky-vaclava-moravce-2-cast/</u>
- <u>https://ekolist.cz/cz/zpravodajstvi/zpravy/lide-mohou-pomoci-vedcum-sledovat-vliv-zmen-pocasi-na-rostliny</u>
- <u>https://www.ekonomickymagazin.cz/2019/02/vse-je-toxicke-o-tom-zda-se-to-projevi-rozhoduje-davka-i/?fbclid=lwAR35tFj31RSTFnjWHWKGkOmjk0it97oUBCpnN6jhylXegwT2g_ogUC9odM</u>
- <u>https://brnensky.denik.cz/z-regionu/luzni-lesy-jako-prirodni-laborator-dominanta-krajiny-zkouma-dopady-zmen-klimatu-20190121.html</u>

List of labelled stations in 2019

- CZ- Lnz (Lanžhot) Proposed as Ecosystem Station Class 1 (PI: Natalia Kowalska) not labelled in 2018, labelling process ends 31.12.2019. We are now working in Action 5 of labelling Step 2.
- CZ BK1 (Bily Križ Forest) Proposed as Ecosystem Station Class 2 (PI: Ladislav Šigut), we are in Action 7 of labelling Step 2.
- CZ wet (Třeboň) Proposed as Associated Station (PI: Jiří Dušek), Sedge-grass marsh, not labelled yet.

1-3 Scientific Highlights from 2019

Researchers from the CzechGlobe participated in five publications on drought 2018 initiative coordinated by ICOS.



ICOS Denmark

Highlights

- The work in 2019 was concentrated on bringing the stations up to the standards, so they can be labelled. We had hoped to label the main stations in 2019, but for all of them some measurements that can only be made during the growing season were missing. They will be made during 2020, which should finalise the labelling of the stations.
- Kim Pilegaard participated in a panel debate about extreme weather at the Carlsberg festival for nature and science in May 2019. (Podcast:
- https://podcasts.apple.com/dk/podcast/bloom/id1482108792?l=da).
- We contributed to the 2nd Nordic ICOS Symposium, 24-25 October 2019, Gothenburg, Sweden.

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

1-3 Scientific Highlights from 2019

The long-term data of CO_2 fluxes from the DK-SOR site provided an excellent background for evaluating the effect of the 2018 summer drought on the carbon sequestration. By making analysis of the monthly trends over the previous 20 years, it was possible to predict the expected uptake in 2018 without drought. The result was, that CO_2 uptake was stimulated in May and June, but severely reduced in July and August, when the soil water reservoir was used up. The reduction due to the drought on an annual basis was 25%.



ICOS Finland

Highlights

Attended events to promote or represent ICOS

- Vesala Timo, committee hearings of the Parliament of Finland, in total five times, February-March 2019, *topics included mitigation to climate change, carbon sinks, etc.*
- Vesala Timo, presentation in a discussion event, organized by Mari Pantsar (Sitra) and Pekka Haavisto (MP, The Greens), 18.2.2019
- Vesala Timo, meeting of The Finnish Society of Sciences and Letters, presentation on the climate effects of forests, peatlands and lakes, 18.2.2019
- Vesala Timo, presentation in public event, carbon sinks and storages, ICOS and SOMPA, Ylä-Satakunnan ympäristöyhdistys ry, Parkano, 28.8.2019
- Vesala Timo, invited presentation, 'Forest harvesting and climate and a public discourse', 9th International Symposium on Atmospheric Sciences, Istanbul Technical University, 24.10.2019
 - This presentation was also given as Kollegium-presentation, Poznan University, 2.10.2019 and seminar presentation at the University of Warsaw, 3.10.2019
- President of Finland visit to FI-Hyy.

Participations in ICOS-related workshops, meetings, conferences

- Viikki Soil Science Seminar, 29 January, 2019, University of Helsinki: Annalea Lohila / Insights into measuring highly variable and sporadic N₂O emissions in a fertile peatland forest.
- EGU 2020: Annalea Lohila, oral presentation in "Peatland management" -session: "Continuous cover forestry as a measure to mitigate environmental impacts of peatland forestry a case study in Southern Finland"
- Climate hour, FMI, Helsinki, for school students, 5.4.2019. Annalea Lohila talked about ICOS and the practical work in it.
- 11 ICOS-Finland scientists attended to the 2nd Nordic ICOS Symposium, 24 25 October, Gothenburg, Sweden
 - ICOS-Finland network presented as poster
 - Invited keynote presentation by Annalea Lohila: 'More than two decades of greenhouse gas research in the Nordics what have we learned and what is there in front of us?'
 - Four other oral presentations by the ICOS-Finland staff members
 - Several poster presentations by the ICOS-Finland staff members
- Raivonen M, Leppänen A, Markkanen T, Aalto T, Kleinen T, Aurela M, Lohila A, Peltola O, Nilsson M, Humphreys E, Burke E, Vesala T.: Site-level simulation of peatland CH4 emissions using JSBACH and HIMMELI. Poster presentation in CHE-VERIFY Joint General Assembly; Reading, UK; 12-14 March 2019.
- RINGO Workshop, Hyytiälä (Finland), 5-8.11.2019, organized by UHEL. Vesala, Mammarella, Vähä, Lohila participated.
- PPNW 2019 (Physical Processes in Natural Water), 9-14.9.2019, Yichang, China: Ivan Mammarella/ Evaluating the bulk transfer approach for sensible and latent heat exchange over a river during the KITEX field campaign; Aki Vähä/CO₂ and CH₄ fluxes over a boreal river measured with eddy covariance.
- Kohonen et al.: 2019: Carbonyl sulfide fluxes on branch and ecosystem scales: relation to photosynthesis, FAST campaign workshop 25.-28.02.2019, Hyytiälä, Finland



- Kohonen et al. 2019: 5 years of COS flux measurements over a boreal forest. 2nd international COS workshop, 11.-14.11.2019, Obergurgl, Austria
- Kohonen et al. 2019: COS flux measurements over a river in Finnish Lapland 2nd international COS workshop, 11.-14.11.2019, Obergurgl, Austria
- Workshops: Strategies to monitor greenhouse gases in urban environments, 1-4 July 2019, Helsinki/Hyytiälä, Finland
- Conference proceedings: Järvi L., Havu M., Toivonen T. and Grimmond C.S.B. (2019). Spatial variability of local-scale CO2emissions in Helsinki. European Meteorological Society Annual Meeting, 9-13.9.2019, Copenhagen, Denmark.
- Conference proceedings: Havu M., Toivonen T. and Järvi L. (2019). Impact of different planning alternatives to minimise carbon dioxide emissions in central Helsinki. Sustainability Science Days, 9-10.5.2019, Helsinki, Finland.

New recruitments

- Minttu Havu, doctoral student working with carbon storage to urban green space
- Hui Zhang, post-doctoral scientist (UHEL), working e.g. with CH₄ flux and vegetation data from FI-Lom
- Henriikka Vekuri, PhD student (FMI), "Solutions for reliably quantifying carbon sequestration in soil"
- Laura Heimsch, PhD student (FMI), "Quantifying the potential of climate-friendly agriculture"

National ICOS scientists in media

- Vesala Timo, tv-discussions about climate change in Huomenta Suomi, MTV (13.3.2019), Sannikka & Ukkola, YLE (15.3.2019), Ilmastouutiset, YLE Kioski (11.5.2019)
- Lohila Annalea, tv-interview on climate research, YLEn Aamu, 5.4.2019
- Laurila Tuomas, interview on YLE web, ICOS-measurements at Pallas Sammaltunturi station, 26.4.2019
- Lohila Annalea, interview for a newspaper article on FMI GHG measurements, Kaleva, 24.5.2019
- Lohila Annalea, radio interview, ICOS-measurements at Pallas, YLE Tiedeykkönen, 9.8.2019
- Lohila Annalea, interview for a newspaper article on carbon budget of agricultural soils, Tekniikka ja Talous, 28.8.2019
- Vesala Timo, Youtube-video, Ilmastotuubi, 6.10.2019
- Vesala Timo, interview in tv-documentary, forest management in Finland, MOT, YLE, 28.10.2019
- Timo Vesala & Werner Kutsch, opinion piece on researchers developing real-time GHG measurements, Helsingin sanomat, 31.10.2019
- Vesala Timo, interview for a newspaper article on forests' carbon sink, Iltalehti, 31.10.2019
- Lohila Annalea, interview for a Finnish forest magazine "Metsälehti" about the FI-Let clear-cut experiment and its results, January 2020
- Kukka-Maaria Erkkilä, interview for a newspaper article about how to measure land carbon sink, Tekniikka ja Talous, 31.5.2019
- Kukka-Maaria Kohonen, interview for a newspaper article about the tree carbon uptake measurements, Helsingin Sanomat 7.11.2019

New funding acquired

• METNET (Methane and soil - tree networks: Adding dimensions to greenhouse-gas studies), Academy of Finland, 01.09.2019 - 31.08.2023. UHEL and UEF, 600 k€



- BiBiFe (Biogeochemical and biophysical feedbacks from forest harvesting to climate change), Academy of Finland, 1.9.2019 - 31.8.2023. UHEL and FMI 900 k€
- STN Multa (Multi-benefit solutions to climate-smart agriculture), Strategic research council, Acad. of Finland, 01.06.2019 31.08.2022, FMI and UHEL 1000 k€
- Funding for doctoral studies: "Solutions for reliably quantifying carbon sequestration in soil", Nessling foundation, PI Henriikka Vekuri (FMI), 120 k€ 2019-2023
- CarboCity "Urban green space solutions in carbon neutral cities" (No: 321527) funded by the Academy of Finland, 2019-2023, 599 598 e (jointly to FMI and UH)
- Funding for doctoral studies "The most optimal green area solutions in present day urban planning to maximise urban carbon stocks" by Tiina and Antti Herlin foundation, 2019, 26 000 e, Pl: M. Havu

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

List of labelled stations in 2019

- Kumpula, (FI-Kmp), ECO associated, PI Leena Järvi
- Utö, (ATM-Uto), ATM Class 2, PI Tuomas Laurila

1-3 Scientific Highlights from 2019

- The climate impacts of conducting a clear cut in a Finnish peatland forest were measured with the eddy covariance method and reported. The clear-cut site emitted a lot of CO₂ after the management. In addition, N₂O emissions were significantly higher than those before the clear cut. The small CH₄ sink of the soil was replaced by a small CH₄ source but the contribution of CH₄ to the total GHG emissions was negligible. (Korkiakoski et al. 2019)
- Map of CH₄ emissions from northern wetlands (>45degN) were estimated using eddy covariance flux measurements (including two Finnish sites) and a machine learning approach. The produced map was compared to results of two process models. The study provides important bottom-up validation data for the top-down approaches, for example. (Peltola et al. 2019)
- Urban land surface model SUEWS (Surface Urban and Energy balance Scheme) has been updated to include the surface exchange of CO₂ allowing to examine processes impacting both CO₂ fluxes and surface energy balance e.g. to support urban planning



ICOS France

Highlights

- ICOS-Scapes demonstration at LSCE May-June 2019
- ICOS-Scapes exposure at University of Paris Saclay March 2020
- Annual ICOS France Science and General Assembly. 26-28 November, Roscoff D. 60 participants, 4 invited keynotes.
- Three days technical workshop organised at Bordeaux June 2019 by D. Berveiller, S. Lafont and C. Chipeaux. 45 participants from France and Wallonie.
- Two permanent Engineer positions were open at Ecosystem stations (FR-Fon, FR-Pue).
- Philippe Ciais (CEA, LSCE) was nominated at the French National Academy of Sciences.
- INRAE has labelled officially the ICOS INRAE part as an INRAE infrastructure (Sept, 2019) that may help securing long term funding of INRAE stations (1 Class1, 5 class-2, 3 associated)
- ICOS was presented during three inaugural or keynote lectures in Autrans (summer school on Adaptation to Climate Change, June), French Academy of Agriculture (special session on Carbon in Ecosystems, Paris, November) and the ERCA winter school organised in Grenoble (January 13th, 2020).

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

List of labelled stations in 2019

Ecosystem:

- Fontainebleau Barbault, FR-Fon, E. Dufrêne, Class1.
- Salles-Bilos, FR-Bil, D. Loustau, Class 2
- Guyaflux, GF-GUY, D. Bonal, Associated
- La Guette, FR-Lgt, S. Gogo, Associated.

1-3 Scientific Highlights from 2019

- As 2018 was not so dry in France, 2019 was conversely a hot and dry growing season with dramatic effects in most ICOS Ecosystem stations. A synthesis should be presented at the upcoming ICOS conference.
- ATC moved in a new building in 2019.



ICOS Germany

Highlights

New stations (ICOS Germany welcomes 3 ATM and 3 ECO stations)

- ATM Zugspitze, Class 2 mountain station operated by UBA (Federal Environment Agency)
- ATM Westerland, Class 2 coastal station operated by UBA (Federal Environment Agency)
- ATM Schauinsland, Class 2 mountain station operated by UBA (Federal Environment Agency)
- ECO Kienhorst, associated forest site operated by LFB (Landesbetrieb Forst Brandenburg)
- ECO Hartheim, associated forest site operated by University of Freiburg
- ECO Braunschweig, associated crop site operated by ZAMF (Centre for Agrometeorological Research of DWD, German Meteorological Service)

New recruits

- Heta Meyer (HSWT, technical staff at ECO site Mooseurach, DE-Msr)
- Janina Klatt (HSWT, scientific staff at ECO site Mooseurach, DE-Msr)
- Sabrina Arnold (DWD, scientific staff for ATM domain)
- Jennifer Müller-Williams (DWD, scientific staff for ATM domain)
- Branko Eisermann (LFB, technical staff at ECO site Kienhorst)
- Ralf Barth (LFB, scientific staff at ECO site Kienhorst, Co-PI)
- Alexander Russ (LFB, scientific staff at ECO site Kienhorst, PI)
- Nils Becker (FZJ, technical staff at ECO site Wüstebach, DE-RuW)
- Cedric Couret (UBA, scientific staff (PI) at ATM site Zugspitze, DE-ZUG and Westerland, DE-WES)
- Ralf Sohmer (UBA, technical staff at ATM site Zugspitze, DE-ZUG)
- Maik Schütze (UBA, technical staff at ATM site Westerland, DE-WES)
- Petra Freund (UBA, technical staff at ATM site Westerland, DE-WES)
- Anita Lämmle (UBA, technical staff at ATM site Westerland, DE-WES)
- Frank Meinhardt (UBA, scientific staff (PI) at ATM site Schauinsland, DE-SSL)
- Frederik Schrader (Thünen Institute, scientific staff at ECO site Gebesee, DE-Geb)
- Ingo Völksch (KIT/IMK-IFU, scientific staff at ECO site Fendt, DE-Fen)
- Andreas Christen (University of Freiburg, PI at ECO site Hartheim)
- Dirk Schindler (University of Freiburg, scientific staff at ECO site Hartheim)
- Dirk Redepennig (University of Freiburg, technical staff at ECO site Hartheim)
- Felix Baab (University of Freiburg, technical staff at ECO site Hartheim)
- Mathias Herbst (welcome back!) (ZAMF/DWD, PI at ECO site Braunschweig)
- Henry Bittig (IOW, scientific staff for OCE SOOP-DE-Finnmaid line)

New funding acquired

- Project KliMoBay at HSWT Potentials of climate protection and adaption in peatlands in Bavaria), 2019-2022, funded by Bavarian State Ministry of the Environment and Consumer Protection, European Regional Development Fund (ERDF)
- Project MOMENT (<u>https://www.ufz.de/index.php?en=46352</u>) at UFZ Towards improved understanding of the coupled water and carbon cycles of terrestrial ecosystems with special focus on extreme events
- Contribution to GBOV (Ground-Based Observations for Validation) with field measurements acquired over Hainich site, operated at University of Göttingen
- EU project SO-CHIC at AWI Southern Ocean Carbon and Heat Impact on Climate), 2019-2023
- Project Carbon storage and release in soils under agricultural and forest use at Technical University Dresden funded by Saxonian LfULG (Aug 2018 Jul 2020)
- Project SPECTROPHABS at IOW Development of pH-monitoring for the Baltic Sea, funded by B.S.H.; SOOP-DE-Finnmaid plays a role as potential carrier and to investigate pH-pCO2 relations



Domain-specific training

- TERENO NEON Carbon Workshop, Düren, Germany, 13-20 July, 2019
- A technical short course on flux measurement fundamentals was held at IMK-IFU (Flux Measurement Fundamentals, KIT/IMK-IFU, Garmisch-Partenkirchen, 29.07. 02.08.2019).
- 2019 IOCCP.BONUS INTEGRAL summer school, with co-funding and participation from RINGO and ICOS OTC, Kristineberg, Sweden, from June 10-19, 2019, see EOS article for more information (<u>https://eos.org/science-updates/training-the-next-generation-of-marine-biogeochemists</u>)
- Eddy Covariance Flux Measurements Winter School hosted at Vuwani Science Resource Centre, Limpopo, South Africa, 10-14 June, 2019, organized and held by Thünen Institute

Personnel training and development

• ATC Training – Sabrina Arnold from DWD

Organised events to promote ICOS

- Public Event "Klimawandelforschung ICOS-D" at HSWT Freising (07.05.2019) within the Annual ICOS Germany Meeting
- Public lecture in Göttingen: Alexander Knohl: 'Wald und Klima: Ein Dialog im Stress', 09.12.2019
- ICOScapes Photo exhibition @ DWD Headquarter, Offenbach, Germany
- ICOScapes Photo exhibition @ BMVI (Federal Ministry of Transport and Digital Infrastructure), Bonn, Germany
- 1st ICOS workshop on strategies to monitor greenhouse gases in urban environments July 1 4, 2019, Helsinki / Hyytiälä, Finland, with ICOS head office, ALU-FR and Helsinki University

Attended events to promote ICOS

- 20th Annual Mer Bleue Peatland Science Workshop, Montreal, Canada, May 27, 2019
- DMG DACH Meeting, Garmisch-Partenkirchen, Germany
- GGMT Conference, Jeju, Korea
- IGI3S Meeting, Paris, France
- EGU conference, Vienna, Austria
- Oceanobs'19 "An Ocean of Opportunity", Honolulu, Hawaii/USA, 16. 20. September 2019
- 14th Winter Colloquium in Eberswalde on results from level II sites in Brandenburg, February 21, 2019.
- Baltic Sea Science Congress 2019, Stockholm, August 19th 23rd 2019

Events where network scientists have been invited as speaker/presenter to represent ICOS

- 2019 Meeting of the DWD's Federal Republic and States Representatives Board, "Treibhausgasmonitoring im DWD; Insitu – Messungen ICOS D Atmosphäre" on March 28, Offenbach, Germany
- 2019 Meeting of German Governmental Institutions, heads of administrative departments, "Klimagas-Messnetz ICOS - Integrated Carbon Observation System", April 8, Zugspitze
- 2019 Meeting of German Governmental Institutions, Presidents, "Klimagas-Messnetz ICOS -Integrated Carbon Observation System", May 2, Zugspitze, Germany
- Opening of the ICOScapes exhibition at DWD, "Klimagase messen Beitrag des DWD zur Überwachung der Treibhausgase (ICOS - Integrated Carbon Observation System)", Offenbach, Germany, Aug 6.



- Opening of the ICOScapes exhibition at BMVI, "Klimagase messen Beitrag des DWD zur Überwachung der Treibhausgase (ICOS - Integrated Carbon Observation System)", Bonn, Germany, Sep 13.
- Public Event "Klimawandelforschung ICOS-D" at HSWT Freising (07.05.2019) within the Annual ICOS Germany Meeting

Major meetings within the National Network

• Annual ICOS Germany Network Meeting at HSWT in Freising, Germany, May 6-7, 2019

Other attended/hosted meetings

- OTC/MSA meeting, Southampton, UK, 18.-19.03.2019
- RINGO annual meeting, Southampton, UK, 20.-22.03.2019
- ICOS OTC sensor workshop, Kiel, Germany, 25.-27.11.2019
- OTC/MSA meeting, Kiel, Germany, 27.-28.11.2019
- ATM MSA meeting in 2019, Gif-sur-Yvette, France
- ATM MSA meeting in 2019, Bologna, Italy
- General Assembly all three meeting in 2019 (Paris, Amsterdam, Helsinki)
- ECO MSA meeting, Marseille, France, 21.-24.05.2019

National ICOS scientists in media

- Article "Das Treibhausgas-Schnüffelnetz" in "Physik in unserer Zeit" (<u>https://doi.org/10.1002/piuz.201901554</u>)
- Interview ICOScapes in cAlle Wetter", HR, Aug 6, link: <u>https://www.hr-fernsehen.de/sendungen-a-z/alle-wetter/sendungen/alle-wetter-vom-06082019,video-98736~_story-sendung-67678.html</u>
- TV Repor "Wasserkreislauf in der Jülicher Börde ist aus dem Lot" on WDR Lokalzeit Aachen, 9. August 2019
- HaPe Schmid gave an interview in the BR program "Unkraut" on 17.6.2019, link: <u>https://www.br.de/mediathek/video/interview-mit-prof-hans-peter-schmid-institutsleiter-imk-</u> <u>ifu-lehrstuhl-fuer-atmosphaerische-umweltforschung-tum-av:5d07ce08899900001a8e96d1</u>
- Article in "Ostsee-Zeitung" on the role of Baltic Sea Research and the SOOP-DE-Finnmaid within the Global Carbon Budget initiative, link: <u>https://www.ostseezeitung.de/Mecklenburg/Rostock/Warnemuender-Ostseeforscher-liefern-Daten-fuer-UN-Klimakonferenz-in-Madrid</u>

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

 Pierrot, D., and T. Steinhoff (2019). Installation of autonomous underway pCO₂ instruments onboard ships of opportunity. NOAA Technical Report, OAR-AOML-50, doi:10.25923/ffz6-0x48, 31 pp



- Schrader, F. (2019). Challenges and perspectives in modelling biosphere-atmosphere exchange of ammonia, PhD thesis at VU Amsterdam.
- Russ, A., Riek, W., Hentschel, R., Hannemann, J., Barth, R., Becker, F. (2019): Water balance during summer drought of 2018 Results from level II sites in Brandenburg. Eberswalder Forstliche Schriftenreihe 67: 11-24.

List of labelled stations in 2019

- Class 1 Atmosphere Station Karlsruhe (KIT), Responsible institution: DWD, Hohenpeissenberg Meteorological Observatory, Station PI: Dagmar Kubistin
- Class 1 Atmosphere Station Ochsenkopf (OXK), Responsible institution: DWD, Hohenpeissenberg Meteorological Observatory, Station PI: Dagmar Kubistin
- Class 1 Atmosphere Station Steinkimmen (STE), Responsible institution: DWD, Hohenpeissenberg Meteorological Observatory, Station PI: Dagmar Kubistin
- Class 1 Ecosystem Station Hohes Holz (DE-HoH), Responsible institution: Helmholtz Centre for Environmental Research UFZ, Station PI: Corinna Rebmann
- Class 1 Ecosystem Station Selhausen Juelich (DE-RuS), Responsible institution: Forschungszentrum Jülich (IBG3: Agrosphere), Station PI: Marius Schmidt
- Associated Ecosystem Station Klingenberg (DE-Kli), Responsible institution: TU Dresden, Station PI: Christian Bernhofer
- Awaiting Step 2 approval for Class 1 Ecosystem Station Tharandt (DE-Tha), Responsible institution: TU Dresden, Station PI: Christian Bernhofer Step 2 of the labelling process has been completed

1-3 Scientific Highlights from 2019

- Contributions of ICOS Germany scientists to the Global Carbon Budget 2019 study
- Contributions of ICOS Germany scientists from all domains to the ICOS Drought Study to be published in a Special Issue in the journal "Philosophical Transactions of the Royal Society B"
- Regional Carbon Budget of Saxony (Germany) Based on Flux Measurements and Inventories: The net carbon budget of managed ecosystems (forests, agriculture) using repeated inventories of carbon pools (biomass, soil) in regular grids and using long-term continuous Eddy Covariance (EC) flux measurements at ICOS sites are in good agreement for forests but not for agricultural land use in Saxony. Ongoing research activities relate to the long-term soil carbon stock change of agricultural soils to check their assumed C neutrality.
- New instrumentation launched on SOOP-DE-Finnmaid, including surface measurements for N₂O, CO, and pH, on top of already established parameters, see also article in "Ostsee-Zeitung, link: <u>https://www.ostsee-zeitung.de/Mecklenburg/Rostock/Warnemuender-Ostseeforscher-liefern-Daten-fuer-UN-Klimakonferenz-in-Madrid</u>, in German



ICOS Italy

Highlights

- Beginning of the Project PIR01_00019 PRO-ICOS_Med ("Upgrading ICOS-Italy Observation Network in the Mediterranean") aimed to enhance research infrastructures, pursuant to Action II.1 of the National Operative Program (PON) – Research and Innovation 2014-2020 (July 2019) – Total funding: € 13.428.028,45
- Beginning of soil sampling at the ecosystem ICOS station of Castelporziano (IT-Cp2) (December 2019) and inspections and soil sampling scheduling for the ecosystem ICOS stations of Renon Selva verde (IT-Ren) and Borgo Cioffi (IT-Bci).
- Strengthening the Italian ICOS Community and the Joint Research Unit.
- The upgrading of the ICOS research infrastructure will concern, firstly, the acquisition of sensors and instruments for the upgrading of the existing national network stations in the Program Area in order to guarantee the qualitative standard indicated by ICOS ERIC, namely: Borgo Cioffi and Bosco di Capodimonte for the ecosystem stations; Lampedusa and Potenza for the atmospheric stations. In particular, for the latter it is intended to acquire the necessary equipment for a continental level 1 station with the construction of a 100 m high tower equipped with sensors and gas sampling system. Furthermore, both the marine and ecosystem network will also be implemented through the creation of a new station for both components on the ICOS site of Lampedusa (Lmp), which is the southernmost site of all European ICOS-RI, and the creation of a new ecosystem station in a transition region (Abruzzo, Collelongo site). PRO-ICOS_MED will also upgrade the three main stations of the Italian ICOS network outside the Program Area, respectively for the terrestrial ecosystems (Castelporziano, IT-Cp2), the atmosphere (Monte Cimone. IT-CMN) and the sea (Paloma), which will represent the reference stations to be used as standard and cross-calibration sites for the stations located within the Program Area.

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

• Urbini L., Giani M., Kovacevic V., Siena G., Cardin V. 2020. Temporal variability of the carbonate system in the Southern Adriatic Sea, Proceedings of 42° CIESM Congress, Cascais, Portugal, 7-11 October 2019, in press.

List of labelled stations in 2019 (labelling at various stages for the mentioned sites)

- Borgo Cioffi (IT-BCi) Ecosystem station, Class 1 Mediterranean crops PI: Vincenzo Magliulo.
- Castelporziano2 (IT-Cp2) Ecosystem station, Class 1 Evergreen Mediterranean Forest PI: Silvano Fares
- Monte Bondone (IT-MBo) Ecosystem station, Class 2 Italian Alps, permanent alpine meadow
 PI: Damiano Gianelle
- Lison (IT-Lsn) Ecosystem station, Class 2 Mediterranean agroecosystem PI: Andrea Pitacco



- Renon Selva Verde (IT-Ren) Ecosystem station, Class 2 Italian Alps, Subalpine forest PI: Leonardo Montagnani
- Arca di Noe (IT-Noe) Ecosystem station, Associated Mediterranean Macchia PI: Donatella Spano
- Bosco Fontana (IT-BFt) Ecosystem station, Associated, Po valley, Oak-Hornbeam forest PI: Giacomo Gerosa
- Capodimonte (IT-PCm) Ecosystem station, Associated Urban park PI: Carlo Calfapietra
- Torgnon (IT-Tor) Ecosystem station, Associated Alpin grassland PI: Edoardo Creemonese
- E2M3A Oceanic station, Southern Adriatic Pit (Adriatic Sea Mediterranean Sea), Surface buoy with ocean mooring PI: Vanessa Cardin
- Miramare (IT-Mambo1) Oceanic station, Adriatic Sea (Mediterranean Sea), Surface buoy with ocean mooring PI: Michele Giani
- Western 1 Oceanic station, Mediterranean Moored Multi-sensor Array (W1M3A) North-Western Mediterranean Sea (Ligurian Sea), Surface buoy with ocean mooring – PI: Roberto Bozzano
- Piattaforma Avanzata LabOratorio Mare Adriatico (PALOMA) Oceanic station, Northern Adriatic Sea, Gulf of Trieste, Beacon– PI: Anna Luchetta
- Lampedusa (Lmp) Atmospheric station, Central Mediterranean Sea, remote island, Open ocean PI: Alcide Di Sarra
- Monte Cimone (IT-CMN) Atmospheric station, Italian northern Apennines, Mountain peak PI: Paolo Cristofanelli
- Plateau Rosa (IT-PRS) Atmospheric station, Northwestern Italian Alps, Mountain peak PI: Francesco Apadula

1-3 Scientific highlights from 2019

- Role of urban ecosystems (urban parks) in Carbon and air pollutants uptake
- Effects of variability in soil water availability and precipitation on ecophysiology and gross primary production in grassland and forest ecosystems
- Evaluation of temporal variation of carbonate system on the ocean-atmosphere carbon exchanges, with a special focus on the Adriatic Sea
- Implementation of the terrestrial biosphere models through eddy covariance data and plant functional traits



ICOS Netherlands

Highlights

- Lutjewad became an official ICOS Class 2 Atmosphere Station in May 2019.
- The Lutjewad long-term CO₂ record contributed to a manuscript "The fingerprint of the summer 2018 drought in Europe on ground based atmospheric CO2", in review.
- Three CIO staff participated in the RINGO annual meeting in Southampton in March 2019.
- A new Picarro N_2O and CO analyser (G5310) was purchased, and was tested at the ATC.
- With respect to the Loobos Ecosystem site, we are working on an upgrade to a class 2 ETC station. While awaiting bureaucratic applications (municipal permissions, etc.), we are preparing to build a new tower up to 38 m, which will be equipped with ICOS-ETC compliant instruments. At the bottom of the tower, a container will be placed to house PC's, pumps, etc. The eddy covariance system was tested over the summer of 2019 in the existing tower. A main power cable will be laid from the nearest access point (~2 km). Currently, we are compiling a list of sensors to be ordered after discussion with ETC. The existing tower is being maintained in the meantime.
- The contribution of ICOS-NL to the ICOS Carbon Portal in 2019 resulted in us taking a leading role in the synthesis of a wide range of studies on the 2018 drought in Europe. The three Dutch ICOS stations reprocessed their long-term record with common calibration standards in the framework of the RINGO project and provided these data for the drought analysis. Extensive use of ICOS data was made in the 15 scientific publications that were written on this event, with many of the ecosystem and atmospheric site-PI's included. Moreover, collaboration with this group was fostered through monthly telecons and a drought workshop, as well as a special session dedicated to the event at EGU. The publications by the drought taskforce are currently under revision, and will be published in 2020 in the journal "Philosophical Transactions of the Royal Society B". All datasets created are stored at the Carbon Portal under a DOI, and publicly available.
- ICOS-NL scientists are continuing to play a leading role in our larger national network called "Ruisdael infrastructure", contributing to the effort of setting up a national observing infrastructure that includes three ICOS sites (Loobos, Cabauw, Lutjewad) as well as a set of auxiliary facilities such as mobile radars, vans, and UAVs, and a national high-resolution modelling capacity. Cabauw data has been made available for several inverse modelling projects such as used for the UK national inventory Report, but also to the annual Obspack release. An important aim is to integrate GHG modelling and measurements in one framework, that can pave the way for future emissions monitoring and verification in the Netherlands. During 2019 the new Ruisdael infrastructure designs for the three Dutch ICOS stations were further developed with instrumentation purchases, deliveries and laboratory testing taking place.
- Wageningen University completed its annual contribution to the Global Carbon Project, as part of our participation in the ICOS Carbon Portal, contributing to the publication of its annual budget that includes many European atmospheric CO₂ measurements from ICOS. A dedicated effort to contribute to the European inverse modelling comparison under the flag of EUROCOM/ICOS also resulted in a scientific publication.



Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

• Frumau, Arnoud (TNO). Long term CH4 and N2O data at the Dutch Cabauw Tower at 8th International Symposium on Non-CO2 Greenhouse Gases (NCGG8), June 12-14, 2019, Amsterdam, The Netherlands.

List of labelled stations in 2019

• Lutjewad Class 2 Atmosphere Station, PIs: Huilin Chen & Bert Scheeren.



ICOS Norway

Highlights

- The terrestrial station at Hurdal (NO-Hur) went through the first phase of the labelling process and was labelled in April 2019
- An annual meeting for ICOS Norway was organised in Bergen 3-4 September. All station PIs participated
- Start of 2 new staff members in NORCE, Richard Sanders, OTC Director and Tobias Steinhoff, OTC Engineer
- Stephen Platt took over the Focal Point role from Cathrine Lund Myhre
- Phase 2 of ICOS Norway received notification of funding form the national funding agency for the period 2021-2024. The suggested budget was cut sharply to 28 million NOK, and negotiations will take place in March 2020 with the Norwegian Research Council to plan the use of the funding allocation.
- The new ICOS OTC engineer, Tobias Steinhoff, started in February 2019. In preparation for the ICOS OTC pCO2 instrument inter-comparison in 2020 several meetings took place. After it was decided that the inter-comparison will take place at the Marine Station Ostende (MSO) at the Flanders Marine Institute (VLIZ) the facilities were visited two times to conduct several tests.
- A training course on a suite of biogeochemical sensors was held in Kristineberg, Sweden, in June 2019. The course was a joint effort between IOCCP and BONUS-INTEGRAL, and OTC contributed with a teacher and a suite of sensors and instruments for the practical training. The course included 28 participants and 16 teachers, and the ocean variables of interest were pH, pCO2, oxygen, and bio-optics.
- The 2nd ICOS OTC Sensor workshop took place at GEOMAR Helmholtz Center for Ocean Research Kiel/Germany in November 2019. During the workshop three companies (Pro Oceanus/Canda, SubCtech/Germany and Sunburst Sensors/USA) presented their instruments and offered hands-on training. The workshop offered the opportunity for ICOS and non-ICOS scientist to interact directly with sensor manufacturers.

Conference and meeting participation

- S. M. Platt, C. L. Myhre, B. Ferré, A. Silyakova, O. Hermansen, I. Pisso, N. Schmidbauer, P. Jansson, A. Stohl, S. Eckhardt, S. Vadakkepuliyambatta, R. Fisher, E.Nisbet, D. Lowry, G. Myhre, J. Mienert, T. Roekmann, Observations of methane in the Arctic, 8th International Symposium on Non-CO2 Greenhouse Gases, Global Challenges and Local Solutions, June 12-14, 2019, Amsterdam, The Netherlands
- S. M. Platt, C. L. Myhre, B. Ferré, A. Silyakova, O. Hermansen, I. Pisso, N. Schmidbauer, P. Jansson, A. Stohl, S. Eckhardt, S. Vadakkepuliyambatta, R. Fisher, E.Nisbet, D. Lowry, G. Myhre, J. Mienert, T. Roekmann, Observations of methane in the Arctic, ICOS Norway meeting in Bergen September 3-4 2019, Bergen, Norway
- S. M. Platt, C. L. Myhre, B. Ferré, A. Silyakova, O. Hermansen, I. Pisso, N. Schmidbauer, P. Jansson, A. Stohl, S. Eckhardt, S. Vadakkepuliyambatta, R. Fisher, E.Nisbet, D. Lowry, G. Myhre, J. Mienert, T. Roekmann, Global and Arctic methane, ACAP Working Group Meeting Arctic Council, September 10-12, 2019, Tromsø, Norway
- Lange, H. (2019). Kommentar: Fluksmålinger med Eddy Kovarians og med kamre. Fagseminar om karbonlagring i jord i åpent lavland/naturbeitemark. SSB Oslo.
- Lange, Holger; Schramm, Marlene; Zhao, Junbin (2019): Analysis of EC 20 Hz raw data from the pilot project at Hoxmark. ICOS MSA Meeting, Marseille.
- Lange, H., M. Schramm, J. Zhao, H. Lange, J. Zhao, H. R. Meissner, M. Schramm and P. Stolle (2019). Preparing for ICOS NO-Hur: first results from a pilot project at Hoxmark. Poster, ICOS Nordic meeting, Göteborg.
- Lange, H., Zhao, J. and Sippel, S. (2019): The terrestrial ICOS site NO-Hur: recent activities and future plans. Presentation, LATICE Annual Meeting, Sundvollen



- Lange, H., J. Zhao and M. Schramm (2019). Analysis of EC 20 Hz raw data from the pilot project at Hoxmark (update). ICOS Norway annual meeting. Bergen.
- Lauvset, S. K., C. L. Myhre, H. Lange, A. Olsen and A. Stohl (2019). ICOS Norway a carbon cycle infrastructure. Geophysical Research Abstracts. 21.
- Schramm, M., H. Lange and J. Zhao (2019). Challenges in establishing an ICOS Ecosystem Station. Geophysical Research Abstracts. 21.
- Lange, H., M. Schramm, S. Sippel and J. Zhao (2019). Nonlinear analysis of very long time series: opportunities and challenges. Geophysical Research Abstracts. 21.
- Becker, M. et al., The Northern European shelf as increasing net sink for CO2, Nordic ICOS conference, October 2019.
- Becker M. et al., ICOS surface ocean CO2 measurements, 9th FerryBox workshop, Genoa, April 2019.
- Becker, M. et al., Mapping coastal ocean CO2 fluxes, North Atlantic surface carbon workshop, NOC, Southampton, March 2019.
- Fransson A., et al., Ward. Effects of sea-ice and biogeochemical processes and storms on underice water fCO2 from winter to spring in the high Arctic Ocean: Implications for sea-air CO2 fluxes. Abstract for poster, IGS conference, Winnipeg, Canada, August 2019.
- Olsen, A. et al., Effects of deep mixing on subpolar North Atlantic carbon, North Atlantic surface carbon workshop, NOC, Southampton, March 2019.
- Skjelvan, I., ICOS Research Infrastructure, NORCE Science Day, Bergen, June 2019

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

Master- and PhD-theses:

- Anne Kari Øhman Meisingset, Anthropogenic Carbon in the Nordic Seas and Arctic Ocean, 1994 to 2007. June 2019, University of Bergen
- Lise Bagne Apelthun, Biogeochemical Investigations on the Atlantic Meridional Transect of R/V Kronprins Haakon 2018. December 2019, University of Bergen

List of labelled stations in 2019

• Hurdal (NO-Hur), Terrestrial station, class 2. PI: Holger Lange

1-3 Scientific highlights from 2019

- Data from the Norwegian ICOS infrastructure was used in an important publication by Nisbet et al., (2019) showing that recent, unexpected, increase in atmospheric methane (CH4) have increased the total abatement measures needed to meet the Paris Agreement goal of limiting warming to 2°C.
- See also the extensive list of international publications published using ICOS Norway marine data in 2019.


ICOS Sweden

Highlights

- The application for running ICOS Sweden during the coming 4 years funding period was approved.
- The 2nd Nordic ICOS Symposium was successfully held in Gothenburg, Sweden with nearly 100 attendees.

Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

- Several contributions related to ICOS Sweden stations by scientists at AGU
- Several contributions related to ICOS Sweden stations by scientists at the 2nd Nordic ICOS Symposium

List of labelled stations in 2019

• Degerö, Class 2 ecosystem station, PI: Mats Nilsson

1-3 Scientific Highlights from 2019

- Contribution to the Drought Task Force from all, but one station (August-November 2019)
- 2nd Nordic ICOS Symposium (October 2019)



ICOS Switzerland

Highlights

ICOS RI and ICOS-CH

- Martin Steinbacher was elected as chair of the ICOS Atmospheric Monitoring Station Assembly in November 2019
- Martin Steinbacher organized the ICOS Atmospheric Monitoring Station Assembly in Bologna, Italy in November 2019
- ICOS-CH is listed on the Swiss Roadmap of Research Infrastructures by the Swiss government for the period 2021-2024, Bern (17.04.2019)
- Excursion to CH-JFJ of the ICOS-CH consortium, Jungfraujoch (18.06.2019)
- The ICOS-CH consortium met for the 7th ICOS-CH Annual Meeting in Birmensdorf. This year the meeting also included scientific presentations by the members of the consortium (12.09.2019)

Atmospheric Site Jungfraujoch

- European Physical Society (EPS) honours the research station Jungfraujoch with the award as historic physics site:
 - https://www.hfsjg.ch/en/publications/news/2019-02-07/
- Research Station Jungfraujoch is recognized as the Chemical Landmark 2019 https://www.hfsjg.ch/en/publications/news/2019-04-25/
- University of Helsinki becomes a new member of the High Altitude Research Stations Jungfraujoch and Gornergrat International Foundation HFSJG (<u>https://www.hfsjg.ch/en/publications/news/2019-04-10/</u>) being in charge of the management of the Jungfraujoch research station.

Ecosystem Site Davos

- CH-DAV Received the Ecosystem Class 1 label (21.11.2019)
- ICOS@Davos meeting: ICOS-CH scientists and staff working at the Davos station met for an informal meeting where the upcoming field season and especially the last steps in the ICOS labelling process were discussed. As last year, this event was very fruitful and necessary in order to all pull together towards the ICOS label (28.03.2019)
- A new excursion guide for Davos station (CH-DAV) was released (12.05.2019) doi: 10.3929/ethzb-000328277
- An excursion to CH-DAV was led by Roman Zweifel, for the 'Sektion Waldernährung Annual meeting' (06.06.2019)
- An archive of webcam images recorded at CH-DAV (2011-2018) was made available to the ICOS community as part of the ICOS 2018 Drought Taskforce:<u>https://fileshare.icos-</u> <u>cp.eu/apps/files/?dir=/Drought%20task%20force/Data/Observations/Phenocam&fileid=10222</u>
 <u>8</u>), 8 August 2019
- The CH-DAV team contributed to the ICOS 2018 Drought Taskforce (Presentation by Mana Gharun in Amsterdam on 22.02.2019, and bi-weekly Webex meetings with all participating ICOS sites between 09.05.2019 and 01.11.2019). The outcome of this taskforce was a special issue on the 2018 Summer Drought in which CH-DAV contributed to four manuscripts submitted to the journal of *Philosophical Transactions of the Royal Society B* (all currently under review)
- Mana Gharun received an ETH Research Grant (ETH-27 19-1) to complete research in CH-DAV: FEVER- Forest Vulnerability to Extreme and Repeated Climatic Stress (for 3 years, started 01 December 2019) <u>https://gl.ethz.ch/research/bage/fever.html</u>



Scientific publications in 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Other publications in 2019

Conference contributions

- Gharun, M., Synchronization test of Eddy Covariance measurements, Presentation at the ICOS Ecosystem Monitoring Station Assembly meeting, 23.-24.05.2019, Marseille, France.
- Gharun, M., Session organization: Scaling terrestrial ecosystem carbon and water response from leaf to continent with observations and simulations, European Geoscience Union General Assembly, 7.-12.04.2019, Vienna, Austria.
- Gharun, M., Hörtnagl, L., Meier, P., Burri, S., Eugster, W., Buchmann, N., Effect of the extreme summer 2018 on the carbon and water budgets of a subalpine coniferous forest in Switzerland. European Geoscience Union General Assembly, 7.-12.04.2019, Vienna, Austria.
- Henne, S., J. Mohn, M. Leuenberger, M. Steinbacher, S. A. Wyss, L. Emmenegger, D. W. Brunner, Swiss Nitrous Oxide and Methane Emissions Estimated by Inverse Modelling, European Geoscience Union General Assembly, April 7-12, 2019, Vienna, Austria,
- Henne, S., J. Mohn, M. Leuenberger, M. Steinbacher, M. K. Vollmer, S. Reimann, L. Emmenegger, D. Brunner, Top-down Validation of non-CO2 Greenhouse Gas Emissions in Support of Swiss National Inventory, 8th International Symposium on Non-CO2 Greenhouse Gases (NCGG8), June 12-14, 2019, Amsterdam, The Netherlands.
- Henne, S., J. Mohn, M. Leuenberger, M. Steinbacher, M. K. Vollmer, S. Reimann, L. Emmenegger, D. W. Brunner, Validation of Swiss Non-CO2 Emissions in Support of National Inventory Reporting, IG3IS Transcom workshop, October 15-18, 2019, Paris, France.
- Pieber, S.M., Tuzson, B., Brunner, D., Henne, S., Jordan, A., Moossen, H., Rothe, M., Steinbacher, M., Emmenegger, L., A decade of continuous high altitude atmospheric CO2 isotope ratio (δ13C, δ18O) measurements at Jungfraujoch, CH, European Geoscience Union General Assembly, 7.-12.04.2019, Vienna, Austria.
- Pieber, S.M., Brunner, D., Henne, S., Jordan, A., Moossen, H., Rothe, M., Steinbacher, M., Tuzson, B., Emmenegger, L., A decade of continuous and discrete trace gas and stable isotope ratio measurements at Jungfraujoch: method comparison. RINGO Annual Scientific Meeting, 2019, Southampton, UK.
- Rigling, A., Etzold, S., Bebi, P., Brang, P., Ferretti, M., Forrester, D., Gärtner, H., Gessler, A., Ginzler, C., Moser, B., Schaub, M., Stroheker, S., Trotsiuk, V., Walthert, L., Zweifel, R., Wohlgemuth, T., 2019: <u>Wie viel Trockenheit ertragen unsere Wälder? Lehren aus extremen Trockenjahren.</u> In: Bründl, M., Schweizer, J. (eds), Forum für Wissen 2019: Lernen aus Extremereignissen, Davos. 39-51.
- Schibig, M., Climate and Environmental Physics Division and Oeschger Centre for Climate Change Research, University of Bern, Switzerland, Presentation ICOS flask sampler performance tests, ICOS MSA atmosphere meeting, 18.-20.11.2019, Bologna Italy.
- Schibig, M., Climate and Environmental Physics Division and Oeschger Centre for Climate Change Research, University of Bern, Switzerland, Combined CO2 and O2 measurements to estimate the fate of carbon emissions, Poster presentation at University of Bern, 16.9.2019.
- Schibig, M., Climate and Environmental Physics Division and Oeschger Centre for Climate Change Research, University of Bern, Switzerland, Combined CO2 and O2 measurements, Poster presentation, 26.5.2019.



- Steinbacher, M., The use of cavity-enhanced laser spectrometers in the European Integrated Carbon Observation System (ICOS) Research Infrastructure, AGAGE (Advanced Global Atmospheric Gases Experiment) Meeting, April 29, 2019, Weggis, Switzerland.
- Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, Training, twinning, and capacity building in support of greenhouse gas observations in data sparse regions, GGMT-2019, September 01-05, 2019, Seogwipo, Jeju-do, South Korea.
- Steinbacher, M., Quality Control of Trace Gas Observations, NIES technical training course on greenhouse gases and air pollutants monitoring in Indonesia, November 24 30, 2019, Tsukuba, Japan.
- Zweifel, R. Where is the ecological memory in trees? Luxembourg Institute of Technology LIST, 29.-30.9.2019.

Reports

- Jordan, A., Moossen, H., Brand, W.A., Rothe, M., Berhanu, T., Nyfeler, P., Schibig, M., Mandrakis, V., Kneißl, R., Eritt, M., Leuenberger, M., Flask comparison on Jungfraujoch, HFSJG, Activity report 2018.
- Leuenberger, M., Levin, I., Hammer, S., Long-term observations of ¹⁴CO2 at Jungfraujoch, HFSJG, Activity report 2018.
- Leuenberger, M., Schibig, M.F., Nyfeler, P., Moret, H., High precision carbon dioxide and oxygen measurements at Jungfraujoch, HFSJG, Activity report 2018.
- Pieber, S.M., Tuzson, B., Steinbacher, M., Emmenegger, L., Continuous measurement of stable CO2 isotopes at Jungfraujoch, Switzerland, HFSJG, Activity report 2018.
- Steinbacher, M., Wyss, S.A., Reimann, S., Hüglin, C., Emmenegger, L., Trace gas observations at Jungfraujoch as part of European Research Infrastructures, HFSJG, Activity report 2018.

Brochures

• Burri, S. (Ed.) (2019): Long-Term Environmental Research: The Davos-Seehornwald Site, Excursion guide. ETH Zurich, Zurich, 35 pp. doi: 10.3929/ethz-b-000328277.

Media articles

- "Groundbreaking climate change research at Jungfraujoch", environmental-expert.com, January 23, 2019.
- "Top of Europe", myscience.ch, February 06, 2019.
- "Jungfraujoch: Auszeichnung für Forschung in schwindelnder Höhe", Berner Oberländer, April 26, 2019.
- "Jungfraujoch: Auszeichnung für Forschung in schwindelnder Höhe", Berner Zeitung, April 26, 2019.
- "Jungfraujoch: Auszeichnung für Spitzenforschung in luftiger Höhe", nzz.ch, April 26, 2019.
- "Jungfraujoch : Lanceur d'alerte pour le climat", l'Alpe, 2019.
- 35 science journalists visit the research station at Jungfraujoch <u>https://www.hfsjg.ch/en/publications/news/2019-07-05/, July 1-5, 2019.</u>
- "ICOS Switzerland: Measuring station in Davos officially labelled", <u>https://usys.ethz.ch/en/news-events/news/archive/2019/11/oekosystem-station-davos-zertifiziert.html</u>, November 25, 2019.
- "ICOS Schweiz: Messstation in Davos offiziell zertifiziert", Gipfel-Zeitung, November 29 December 6, 2019.
- "How a photographer got this amazing mountaintop shot", National Geographic, https://www.nationalgeographic.com.au/people/how-a-photographer-got-this-amazing-mountaintop-shot.aspx, December 02, 2019.



Radio and television

- "Jungfraujoch: Laboratoire d'exception", RTS Un, Le journal 19h30, April 27, 2019.
- "Premiata la Sfinge", RSI LA 1, Telegiornale sera, April 27, 2019.

List of labelled stations in 2019

- Jungfraujoch, Atmosphere, ICOS-Station PI: Martin Steinbacher; Station Supervising PI: Markus Leuenberger (labelled on 31 May 2018)
- Davos, Ecosystem, ICOS-Station PI: Mana Gharun (labelled on 21 November 2019)

1-3 Scientific Highlights from 2019

- The ICOS Class 1 site CH-DAV participated in different international projects: OXYFLUX (Göttingen University), June 2019; Airborne Prism Experiment (APEX, Department of Geography, University of Zürich), July 2019; Mercury dynamics and fate in forest ecosystems (State Key Laboratory of Environmental Geochemistry, China, and University of Basel), November 2019.
- Final quality-controlled eddy covariance and meteorological dataset from CH-DAV (until end of 2018) was released as part of the ICOS 2018 Drought taskforce: Drought-2018 ecosystem eddy covariance flux product in FLUXNET-Archive format release 2019-1. Drought 2018 Team and ICOS Ecosystem Thematic Centre, DOI: 10.18160/PZDK-EF78, ICOS Carbon Portal.
- Data from past measurements at CH-DAV enabled the ICOS ETC to investigate performance metrics of the ICOS-conform infrared gas analyzer sensor LI-7200 in comparison to the widely applied, but not ICOS-conform sensor LI-7500. October 2019.
- Within RINGO, the unique concurrent measurements of a range of GHGs at CH-DAV are used to outline harmonized data processing steps for non-CO₂ eddy covariance data measured at ICOS stations (Lukas Hörtnagl).



ICOS UK

Highlights

- The UK National Network hold regular 6 monthly meetings to discuss network progress, highlights and achievements. The meetings also include going over the ICOS General Assembly meeting material. The last meeting was in November 2019.
- Our Station PI for the PAP-SO ocean station has given a talk promoting ICOS RI at the EMSO Conference: Preparing for a decade of ocean science. February 2020
- The University of East Anglia (The Weybourne Atmospheric Observatory station) are collaborators on an ICOS infrastructure project quantifying ffCO2 using APO in Heidelberg. Central Radiation Laboratory annual report.
- The Weybourne Atmospheric Observatory station have received funding from NCAS.
- The National Oceanography Centre and University of Exeter, UK, organised and hosted a RINGO annual meeting during 20-22 March 2019 and The ICOS Symposium on the North Atlantic carbon cycle on 19 March 2019 with great success.
- We have a new atmospheric station, Ridge Hill, from the University of Bristol. Funding is received from BEIS (Department for Business, Energy and Industrial Strategy).
- In April 2019 the UK officially joined the Ocean Thematic Centre as co-hosts with Norway. Professor Andrew Watson (University of Exeter, UK) is Deputy Director.

Other publications in 2019

- The UK designed and created a brochure to represent the Ocean Thematic Centre, highlighting what we do and what potential new members can expect in return upon joining. This was created with our Norwegian colleagues, with whom we co-host the Ocean Thematic Centre.
- The Weybourne Atmospheric Observatory had a new student, Susie Featherston, who completed an 8-week internship. Title for that was "Quantifying fossil fuel CO2 in the atmosphere" and used WAO data.

1-3 Scientific Highlights from 2019

• The UK have created and designed a brochure that will be circulated at future meetings to promote ICOS RI and the Ocean Thematic Centre as 3 of our stations are members of the Ocean Thematic Centre, of which the UK jointly host with the University of Bergen and NORCE Research in Norway. November/December 2019.



Main ICOS internal meetings

- Financial Committee meeting, 07/03/2019, Amsterdam, Netherlands
- 8th General Assembly, 21-22/05/2019, Paris, France
- ICOS Ecosystem MSA, 22-24/05/2019, Marseille, France
- Financial Committee meeting, 27/08/2019, WebEx, Helsinki, Finland
- Carbon Portal visit to Head Office, 22/08/2019, Helsinki, Finland
- 9th General Assembly, 30/09/2019, Amsterdam, Netherlands
- Financial Committee meeting, 15/10/2019, WebEx, Helsinki, Finland
- 10th General Assembly, 20-21/11/2019, Helsinki, Finland
- ICOS Atmosphere MSA, 14-16/05/2019, Gif-sur-Yvette, France
- ICOS Atmosphere MSA, 18-20/11/2019, Bologna, Italy
- ICOS Ocean MSA, 18/03/2019, NOC, Southampton, UK
- ICOS Ocean MSA, 27-28/11/2019, GEOMAR, Kiel, Germany
- ICOS RICOM face-to-face meeting, 26-28/2/2019, Saclay, France
- ICOS RICOM face-to-face meeting, 24-26/9/2019, Zürich, Switzerland
- ICOS RICOM online meetings, 11 times.

Main ICOS National Network meetings

- 5th ICOS Belgium annual meeting, 20/06/2019, Lochristi, Belgium
- Annual ICOS Germany Network Meeting, 6-7/05/2019, Freising, Germany
- 7th ICOS-CH Annual Meeting, 12/09/2019, Birmensdorf, Switzerland
- ICOS Belgium Science Conference 3/10/2019 ICOS Belgium, Antwerp, Belgium
- ICOS Nordic, 24-25/10/2019 ICOS Sweden, Gothenburg, Sweden
- ICOS Scientific days 26-28/11/2019 ICOS France, Roscoff, France

Main events organised or co-organised by ICOS

Events, trainings, workshops and exhibitions:

- RINGO summer school, 16-20/09/2019, Brno, Czech Republic
- RINGO Workshop, 5-8/11/2019, Hyytiälä, Finland
- 1st ICOS workshop on 'strategies to monitor greenhouse gases in urban environments', 1– 4/07/2019, Hyytiälä, Helsinki, Finland
- RINGO Annual Meeting, 19-22/3/2019, Southampton, UK
- ICOS Symposium on 'North Atlantic and adjacent seas carbon cycle', 19/3/2019, NOC, Southampton, UK. Organised in connection with the RINGO Annual Science meeting
- ICOS OTC Sensor Workshop, 25-27/11/2019, Kiel, Germany
- Training course on a suite of biogeochemical sensors, 10-21/06/2019, Kristineberg, Sweden
- Standardized observations are the base of all climate science, side-event at COP25, 4/12/2019, Madrid, Spain
- ICOScapes exhibition 4-26 March 2019, Versailles Saint Quentin University, Guyancourt, France.
- ICOScapes exhibition 26-30 June 2019, Klima Pavillion, Jena, Germany.
- ICOScapes exhibition 15 August-15 September 2019, the German Weather Service, Offenbach, Germany.
- ICOScapes exhibition on 15 September-15 October 2019, the Federal Ministry of Transport and Digital Infrastructure, Bonn, Germany.



Main events attended by ICOS ERIC

- ENVRI-FAIR Kick-off meeting, 14-16/1/2019, Prague, Czech Republic
- Common CHE and VERIFY Meeting, 12-14/3/2019, Reading, UK
- ENVRI Week, 25-29/3/2019, Helsinki, Finland
- EGU General Assembly 2019, 07-12/04/2019, Vienna, Austria
- RISCAPE Workshop, 24-26/4/2019, Prague, Czech Republic
- EuroGOOS 9th Ferrybox Workshop, 24-26/4/2019, Genoa, Italy
- ERIC Forum meeting, 07-08/05/2019, Oslo, Norway
- E-Shape kick-off meeting, 9-10/5/2019, Cannes, France
- SEACRIFOG Annual Meeting, 13-16/5/2019, Cape Town, South Africa
- ENVRIplus Final Event, 4/6/2019, Brussels, Belgium
- Third NextGEOSS summit, 1-2/7/2019, Lisbon, Portugal
- EuroGEOSS workshop, 3-5/7/2019, Lisbon, Portugal
- 4th AfriGEO Symposium, 13-16/8/2019, Nairobi, Kenya
- Ocean Obs19 Conference, 16-20/9/2019, Waikiki, Honolulu, Hawaii, USA
- PANACEA First Scientific Conference, 23-24/9/2019, Heraklion, Greece (remote participation)
- 16th Krycklan Catchment Symposium, 25/10/2019, Umeå, Sweden
- AOGEO Symposium, 2-3/11/2019, Canberra, Australia
- GEO Week XVI, 4-8/11/2019, Canberra, Australia
- DANUBIUS Final Meeting, 18-19/11/2019, Rome, Italy
- 3rd Polar Data Forum, 18-22/11/2019 (Organized by INTAROS, EU Arctic Cluster, IASC-SAON Arctic Data Committee, SOOS, World Data System etc.), FMI, Helsinki, Finland.
- COP25, 2-5/12/2019, Madrid, Spain
- NSF EarthCube Workshop for Shipboard Ocean Time Series Data, 13-15/9/2019, Univ. Honolulu, Hawaii, USA

Main Publications 2019

Full list of ICOS RI publications, including the National Networks is available at: <u>https://www.icos-cp.eu/references</u>

Acosta, M., Dušek, J., Chamizo, S., Serrano-Ortiz, P., & Pavelka, M. (2019). Autumnal fluxes of CH4 and CO2 from Mediterranean reed wetland based on eddy covariance and chamber methods. *Catena*, *183*, 104191. https://doi.org/10.1016/j.catena.2019.104191

Alice Courtois, E., Stahl, C., Burban, B., Van Den Berge, J., Berveiller, D., Bréchet, L., … August Janssens, I. (2019). Automatic high-frequency measurements of full soil greenhouse gas fluxes in a tropical forest. *Biogeosciences*, *16*(3), 785–796. https://doi.org/10.5194/bg-16-785-2019

Araujo, M., Noriega, C., Medeiros, C., Lefèvre, N., Ibánhez, J. S. P., Flores Montes, M., ... Santos, M. de L. (2019). On the variability in the CO2 system and water productivity in the western tropical Atlantic off North and Northeast Brazil. *Journal of Marine Systems*, *189*, 62–77. https://doi.org/10.1016/j.jmarsys.2018.09.008

Ariza-Carricondo, C., Di Mauro, F., De Beeck, M. O., Roland, M., Gielen, B., Vitale, D., ... Papale, D. (2019). A comparison of different methods for assessing leaf area index in four canopy types. *Central European Forestry Journal*, *65*(2), 67–80. https://doi.org/10.2478/forj-2019-0011

Ariza-Carricondo, C., Di Mauro, F., De Beeck, M. O., Roland, M., Gielen, B., Vitale, D., ... Papale, D. (2019). A comparison of different methods for assessing leaf area index in four canopy types. *Central European Forestry Journal*, *65*(2), 67–80. https://doi.org/10.2478/forj-2019-0011



Baeten, L., Bruelheide, H., van der Plas, F., Kambach, S., Ratcliffe, S., Jucker, T., ... Scherer-Lorenzen, M. (2019). Identifying the tree species compositions that maximize ecosystem functioning in European forests. *Journal of Applied Ecology*, *56*(3), 733–744. https://doi.org/10.1111/1365-2664.13308

Balzarolo, M., Valdameri, N., Fu, Y. H., Schepers, L., Janssens, I. A., & Campioli, M. (2019). Different determinants of radiation use efficiency in cold and temperate forests. *Global Ecology and Biogeography*, *28*(11), 1649–1667. https://doi.org/10.1111/geb.12985

Bange, H. W., Arévalo-Martínez, D. L., Paz, M. de la, Farías, L., Kaiser, J., Kock, A., ... Wilson, S. T. (2019). A harmonized nitrous oxide (N 2 O) ocean observation network for the 21st century. *Frontiers in Marine Science*, *6*(APR). https://doi.org/10.3389/fmars.2019.00157

Bastos, A., Ciais, P., Chevallier, F., Rödenbeck, C., Ballantyne, A. P., Maignan, F., ... Zhu, D. (2019). Contrasting effects of CO2 fertilization, land-use change and warming on seasonal amplitude of Northern Hemisphere CO2 exchange. *Atmospheric Chemistry and Physics*, *19*(19), 12361–12375. https://doi.org/10.5194/acp-19-12361-2019

Bechtold, M., De Lannoy, G. J. M., Koster, R. D., Reichle, R. H., Mahanama, S. P., Bleuten, W., ... Tiemeyer, B. (2019). PEAT-CLSM: A Specific Treatment of Peatland Hydrology in the NASA Catchment Land Surface Model. *Journal of Advances in Modeling Earth Systems*, *11*(7), 2130–2162. https://doi.org/10.1029/2018MS001574

Berhanu, T. A., Hoffnagle, J., Rella, C., Kimhak, D., Nyfeler, P., & Leuenberger, M. (2019). High-precision atmospheric oxygen measurement comparisons between a newly built CRDS analyzer and existing measurement techniques. *Atmospheric Measurement Techniques*, *12*(12), 6803–6826. https://doi.org/10.5194/amt-12-6803-2019

Berhongaray, G., Cotrufo, F. M., Janssens, I. A., & Ceulemans, R. (2019). Below-ground carbon inputs contribute more than above-ground inputs to soil carbon accrual in a bioenergy poplar plantation. *Plant and Soil*, *434*(1–2), 363–378. https://doi.org/10.1007/s11104-018-3850-z

Besnard, S., Carvalhais, N., Altaf Arain, M., Black, A., Brede, B., Buchmann, N., ... Reichstein, M. (2019). Memory effects of climate and vegetation affecting net ecosystem CO2 fluxes in global forests. *PLoS ONE*, *14*(2), e0211510. https://doi.org/10.1371/journal.pone.0211510

Bigeard, G., Coudert, B., Chirouze, J., Er-Raki, S., Boulet, G., Ceschia, E., & Jarlan, L. (2019). Ability of a soil-vegetation-atmosphere transfer model and a two-source energy balance model to predict evapotranspiration for several crops and climate conditions. *Hydrology and Earth System Sciences*, *23*(12), 5033–5058. https://doi.org/10.5194/hess-23-5033-2019

Billesbach, D. P., Chan, S. W., Cook, D. R., Papale, D., Bracho-Garrillo, R., Verfallie, J., ... Biraud, S. C. (2019). Effects of the Gill-Solent WindMaster-Pro "w-boost" firmware bug on eddy covariance fluxes and some simple recovery strategies. *Agricultural and Forest Meteorology*, *265*, 145–151. https://doi.org/10.1016/j.agrformet.2018.11.010

Billesbach, D. P., Chan, S. W., Cook, D. R., Papale, D., Bracho-Garrillo, R., Verfallie, J., ... Biraud, S. C. (2019). Effects of the Gill-Solent WindMaster-Pro "w-boost" firmware bug on eddy covariance fluxes and some simple recovery strategies. *Agricultural and Forest Meteorology*, *265*, 145–151. https://doi.org/10.1016/j.agrformet.2018.11.010

Bowring, S. P. K., Lauerwald, R., Guenet, B., Zhu, D., Guimberteau, M., Tootchi, A., ... Ciais, P. (2019). ORCHIDEE MICT-LEAK (r5459), a global model for the production, transport, and transformation of dissolved organic carbon from Arctic permafrost regions - Part 1: Rationale, model description, and simulation protocol. *Geoscientific Model Development*, *12*(8), 3503–3521. https://doi.org/10.5194/gmd-12-3503-2019



Box, J. E., Colgan, W. T., Christensen, T. R., Schmidt, N. M., Lund, M., Parmentier, F. J. W., ... Olsen, M. S. (2019). Key indicators of Arctic climate change: 1971-2017. *Environmental Research Letters*, *14*(4), 45010. https://doi.org/10.1088/1748-9326/aafc1b

Brændholt, A., Ibrom, A., Ambus, P., Larsen, K. S., & Pilegaard, K. (2019). Combining a quantum cascade laser spectrometer with an automated closed-chamber system for δ 13C measurements of forest soil, tree stem and tree root CO2 fluxess. *Forests*, *10*(5), 432. https://doi.org/10.3390/f10050432

Campbell, J. L., & Laudon, H. (2019). Carbon response to changing winter conditions in northern regions: Current understanding and emerging research needs. *Environmental Reviews*, *27*(4), 545–566. https://doi.org/10.1139/er-2018-0097

Campeau, A., Bishop, K., Amvrosiadi, N., Billett, M. F., Garnett, M. H., Laudon, H., ... Wallin, M. B. (2019). Current forest carbon fixation fuels stream CO 2 emissions. *Nature Communications*, *10*(1), 1876. https://doi.org/10.1038/s41467-019-09922-3

Cernusak, L. A., Haverd, V., Brendel, O., Le Thiec, D., Guehl, J. M., & Cuntz, M. (2019). Robust Response of Terrestrial Plants to Rising CO2. *Trends in Plant Science*, *24*(7), 578–586. https://doi.org/10.1016/j.tplants.2019.04.003

Chen, J. M., Ju, W., Ciais, P., Viovy, N., Liu, R., Liu, Y., & Lu, X. (2019). Vegetation structural change since 1981 significantly enhanced the terrestrial carbon sink. *Nature Communications*, *10*(1). https://doi.org/10.1038/s41467-019-12257-8

Chi, J., Nilsson, M. B., Kljun, N., Wallerman, J., Fransson, J. E. S., Laudon, H., ... Peichl, M. (2019). The carbon balance of a managed boreal landscape measured from a tall tower in northern Sweden. *Agricultural and Forest Meteorology*, *274*, 29–41. https://doi.org/10.1016/j.agrformet.2019.04.010

Chiesa, M., Bignotti, L., Finco, A., Marzuoli, R., & Gerosa, G. (2019). Size-resolved aerosol fluxes above a broadleaved deciduous forest. *Agricultural and Forest Meteorology*, *279*, 107757. https://doi.org/10.1016/j.agrformet.2019.107757

Collalti, A., Thornton, P. E., Cescatti, A., Rita, A., Borghetti, M., Nolè, A., ... Matteucci, G. (2019). The sensitivity of the forest carbon budget shifts across processes along with stand development and climate change. *Ecological Applications*, *29*(2). https://doi.org/10.1002/eap.1837

Conil, S., Helle, J., Langrene, L., Laurent, O., Delmotte, M., & Ramonet, M. (2019). Continuous atmospheric CO2, CH4 and CO measurements at the Observatoire Pérenne de l'Environnement (OPE) station in France from 2011 to 2018. *Atmospheric Measurement Techniques*, *12*(12), 6361–6383. https://doi.org/10.5194/amt-12-6361-2019

Conte, A., Fares, S., Salvati, L., Savi, F., Matteucci, G., Mazzenga, F., ... Montagnani, L. (2019). Ecophysiological Responses to Rainfall Variability in Grassland and Forests Along a Latitudinal Gradient in Italy. *Frontiers in Forests and Global Change*, *2*. https://doi.org/10.3389/ffgc.2019.00016

Crabbe, R. A., Janouš, D., Dařenová, E., & Pavelka, M. (2019). Exploring the potential of LANDSAT-8 for estimation of forest soil CO 2 efflux. *International Journal of Applied Earth Observation and Geoinformation*, 77, 42–52. https://doi.org/10.1016/j.jag.2018.12.007

Dangal, S. R. S., Tian, H., Xu, R., Chang, J., Canadell, J. G., Ciais, P., ... Zhang, B. (2019). Global Nitrous Oxide Emissions From Pasturelands and Rangelands: Magnitude, Spatiotemporal Patterns, and Attribution. *Global Biogeochemical Cycles*, *33*(2), 200–222. https://doi.org/10.1029/2018GB006091

Darenova, E., Szatniewska, J., Acosta, M., & Pavelka, M. (2019). Variability of stem CO2 efflux response totemperatureoverthedielperiod.*TreePhysiology*,*39*(5),877–887.https://doi.org/10.1093/treephys/tpy134



De Marco, A., Proietti, C., Anav, A., Ciancarella, L., D'Elia, I., Fares, S., ... Leonardi, C. (2019). Impacts of air pollution on human and ecosystem health, and implications for the National Emission Ceilings Directive: Insights from Italy. *Environment International*, *125*, 320–333. https://doi.org/10.1016/j.envint.2019.01.064

Deirmendjian, L., Anschutz, P., Morel, C., Mollier, A., Augusto, L., Loustau, D., ... Abril, G. (2019). Importance of the vegetation-groundwater-stream continuum to understand transformation of biogenic carbon in aquatic systems – A case study based on a pine-maize comparison in a lowland sandy watershed (Landes de Gascogne, SW France). *Science of the Total Environment*, *661*, 613–629. https://doi.org/10.1016/j.scitotenv.2019.01.152

Delon, C., Galy-Lacaux, C., Serça, D., Personne, E., Mougin, E., Adon, M., ... Tagesson, T. (2019). Modelling land-atmosphere daily exchanges of NO, NH3, and CO2 in a semi-arid grazed ecosystem in Senegal. *Biogeosciences*, *16*(9), 2049–2077. https://doi.org/10.5194/bg-16-2049-2019

Djomo, S. N., De Groote, T., Gobin, A., Ceulemans, R., & Janssens, I. A. (2019). Combining a land surface model with life cycle assessment for identifying the optimal management of short rotation coppice in Belgium. *Biomass and Bioenergy*, *121*, 78–88. https://doi.org/10.1016/j.biombioe.2018.12.010

Druel, A., Ciais, P., Krinner, G., & Peylin, P. (2019). Modeling the Vegetation Dynamics of Northern Shrubs and Mosses in the ORCHIDEE Land Surface Model. *Journal of Advances in Modeling Earth Systems*, *11*(7), 2020–2035. https://doi.org/10.1029/2018MS001531

Dumortier, P., Aubinet, M., Lebeau, F., Naiken, A., & Heinesch, B. (2019). Point source emission estimation using eddy covariance: Validation using an artificial source experiment. *Agricultural and Forest Meteorology*, *266–267*, 148–156. https://doi.org/10.1016/j.agrformet.2018.12.012

Efren, L. B., Exbrayat, J. F., Lund, M., Christensen, T. R., Tamstorf, M. P., Slevin, D., ... Williams, M. (2019). Evaluation of terrestrial pan-Arctic carbon cycling using a data-assimilation system. *Earth System Dynamics*, *10*(2), 233–255. https://doi.org/10.5194/esd-10-233-2019

Esquivel-Muelbert, A., Baker, T. R., Dexter, K. G., Lewis, S. L., Brienen, R. J. W., Feldpausch, T. R., ... Phillips, O. L. (2019). Compositional response of Amazon forests to climate change. *Global Change Biology*, *25*(1), 39–56. https://doi.org/10.1111/gcb.14413

Fan, L., Wigneron, J. P., Ciais, P., Chave, J., Brandt, M., Fensholt, R., ... Peñuelas, J. (2019). Satellite-observed pantropical carbon dynamics. *Nature Plants*, *5*(9), 944–951. https://doi.org/10.1038/s41477-019-0478-9

Fares, S., Alivernini, A., Conte, A., & Maggi, F. (2019). Ozone and particle fluxes in a Mediterranean forest predicted by the AIRTREE model. *Science of the Total Environment*, *682*, 494–504. https://doi.org/10.1016/j.scitotenv.2019.05.109

Fernández-Martínez, M., Sardans, J., Chevallier, F., Ciais, P., Obersteiner, M., Vicca, S., … Peñuelas, J. (2019). Global trends in carbon sinks and their relationships with CO2 and temperature. *Nature Climate Change*, *9*(1), 73–79. https://doi.org/10.1038/s41558-018-0367-7

Fischer, F. J., Maréchaux, I., & Chave, J. (2019). Improving plant allometry by fusing forest models and remote sensing. *New Phytologist*, *223*(3), 1159–1165. https://doi.org/10.1111/nph.15810

Fitzky, A. C., Sandén, H., Karl, T., Fares, S., Calfapietra, C., Grote, R., ... Rewald, B. (2019). The Interplay Between Ozone and Urban Vegetation—BVOC Emissions, Ozone Deposition, and Tree Ecophysiology. *Frontiers in Forests and Global Change*, *2*. https://doi.org/10.3389/ffgc.2019.00050

Frey, M., Sha, M. K., Hase, F., Kiel, M., Blumenstock, T., Harig, R., ... Orphal, J. (2019). Building the COllaborative Carbon Column Observing Network (COCCON): Long-term stability and ensemble performance of the EM27/SUN Fourier transform spectrometer. *Atmospheric Measurement Techniques*, *12*(3), 1513–1530. https://doi.org/10.5194/amt-12-1513-2019



Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., ... Zaehle, S. (2019). Global carbon budget 2019. *Earth System Science Data*, *11*(4), 1783–1838. https://doi.org/10.5194/essd-11-1783-2019

Fröb, F., Olsen, A., Becker, M., Chafik, L., Johannessen, T., Reverdin, G., & Omar, A. (2019). Wintertime fCO 2 Variability in the Subpolar North Atlantic Since 2004. *Geophysical Research Letters*, *46*(3), 1580–1590. https://doi.org/10.1029/2018GL080554

Geng, M. S., Christensen, J. H., & Christensen, T. R. (2019). Potential future methane emission hot spots in Greenland. *Environmental Research Letters*, *14*(3), 35001. https://doi.org/10.1088/1748-9326/aaf34b

Gonzaga Gomez, L., Loubet, B., Lafouge, F., Ciuraru, R., Buysse, P., Durand, B., ... Boissard, C. (2019). Comparative study of biogenic volatile organic compounds fluxes by wheat, maize and rapeseed with dynamic chambers over a short period in northern France. *Atmospheric Environment*, *214*, 116855. https://doi.org/10.1016/j.atmosenv.2019.116855

Gourlez de la Motte, L., Dumortier, P., Beckers, Y., Bodson, B., Heinesch, B., & Aubinet, M. (2019). Herd position habits can bias net CO 2 ecosystem exchange estimates in free range grazed pastures. *Agricultural and Forest Meteorology*, *268*, 156–168. https://doi.org/10.1016/j.agrformet.2019.01.015

Grossiord, C., Christoffersen, B., Alonso-Rodríguez, A. M., Anderson-Teixeira, K., Asbjornsen, H., Aparecido, L. M. T., ... McDowell, N. G. (2019). Precipitation mediates sap flux sensitivity to evaporative demand in the neotropics. *Oecologia*, *191*(3), 519–530. https://doi.org/10.1007/s00442-019-04513-x

Haro, K., Ouarma, I., Nana, B., Bere, A., Tubreoumya, G. C., Kam, S. Z., ... Koulidiati, J. (2019). Assessment of CH4 and CO2 surface emissions from Polesgo's landfill (Ouagadougou, Burkina Faso) based on static chamber method. *Advances in Climate Change Research*, *10*(3), 181–191. https://doi.org/10.1016/j.accre.2019.09.002

Hartman, S. E., Humphreys, M. P., Kivimäe, C., Woodward, E. M. S., Kitidis, V., McGrath, T., ... Nightingale, P. (2019). Seasonality and spatial heterogeneity of the surface ocean carbonate system in the northwest European continental shelf. *Progress in Oceanography*, *177*, 101909. https://doi.org/10.1016/j.pocean.2018.02.005

Hastie, A., Lauerwald, R., Ciais, P., & Regnier, P. (2019). Aquatic carbon fluxes dampen the overall variation of net ecosystem productivity in the Amazon basin: An analysis of the interannual variability in the boundless carbon cycle. *Global Change Biology*, *25*(6), 2094–2111. https://doi.org/10.1111/gcb.14620

Hayes, F., Mills, G., Alonso, R., González-Fernández, I., Coyle, M., Grünhage, L., ... Marzuoli, R. (2019). A Site-Specific Analysis of the Implications of a Changing Ozone Profile and Climate for Stomatal Ozone Fluxes in Europe. *Water, Air, and Soil Pollution, 230*(1). https://doi.org/10.1007/s11270-018-4057-x

He, Y., Peng, S., Liu, Y., Li, X., Wang, K., Ciais, P., ... Zhu, Q. (2019). Global vegetation biomass production efficiency constrained by models and observations. *Global Change Biology*, *26*(3), 1474–1484. https://doi.org/10.1111/gcb.14816

Helfter, C., Mullinger, N., Vieno, M., O'Doherty, S., Ramonet, M., Palmer, P. I., & Nemitz, E. (2019). Countryscale greenhouse gas budgets using shipborne measurements: A case study for the UK and Ireland. *Atmospheric Chemistry and Physics*, *19*(5), 3043–3063. https://doi.org/10.5194/acp-19-3043-2019

Holding, T., Ashton, I. G., Shutler, J. D., Land, P. E., Nightingale, P. D., Rees, A. P., ... Donlon, C. J. (2019). The fluxengine air-sea gas flux toolbox: Simplified interface and extensions for in situ analyses and multiple sparingly soluble gases. *Ocean Science*, *15*(6), 1707–1728. https://doi.org/10.5194/os-15-1707-2019



Horemans, J. A., Arriga, N., & Ceulemans, R. (2019). Greenhouse gas budget of a poplar bioenergy plantation in Belgium: CO2 uptake outweighs CH4 and N2O emissions. *GCB Bioenergy*, *11*(12), 1435–1443. https://doi.org/10.1111/gcbb.12648

Huang, M., Piao, S., Ciais, P., Peñuelas, J., Wang, X., Keenan, T. F., ... Janssens, I. A. (2019). Air temperature optima of vegetation productivity across global biomes. *Nature Ecology and Evolution*, *3*(5), 772–779. https://doi.org/10.1038/s41559-019-0838-x

Hurdebise, Q., Aubinet, M., Heinesch, B., & Vincke, C. (2019). Increasing temperatures over an 18-year period shortens growing season length in a beech (Fagus sylvatica L.)-dominated forest. *Annals of Forest Science*, *76*(3). https://doi.org/10.1007/s13595-019-0861-8

Ivakhov, V. M., Paramonova, N. N., Privalov, V. I., Zinchenko, A. V., Loskutova, M. A., Makshtas, A. P., ... Asmi, E. (2019). Atmospheric Concentration of Carbon Dioxide at Tiksi and Cape Baranov Stations in 2010–2017. *Russian Meteorology and Hydrology*, 44(4), 291–299. https://doi.org/10.3103/S1068373919040095

Jakovljević, T., Marchetto, A., Lovreškov, L., Potočić, N., Seletković, I., Indir, K., ... Jurinjak Tušek, A. (2019). Assessment of Atmospheric Deposition and Vitality Indicators in Mediterranean Forest Ecosystems. *Sustainability*, *11*(23), 6805. https://doi.org/10.3390/su11236805

Järvi, L., Havu, M., Ward, H. C., Bellucco, V., McFadden, J. P., Toivonen, T., ... Grimmond, C. S. B. (2019). Spatial Modeling of Local-Scale Biogenic and Anthropogenic Carbon Dioxide Emissions in Helsinki. *Journal of Geophysical Research: Atmospheres*, *124*(15), 8363–8384. https://doi.org/10.1029/2018JD029576

Jauhiainen, J., Alm, J., Bjarnadottir, B., Callesen, I., Christiansen, J. R., Clarke, N., ... Laiho, R. (2019). Reviews and syntheses: Greenhouse gas exchange data from drained organic forest soils-A review of current approaches and recommendations for future research. *Biogeosciences*, *16*(23), 4687–4703. https://doi.org/10.5194/bg-16-4687-2019

Jiang, L. Q., Carter, B. R., Feely, R. A., Lauvset, S. K., & Olsen, A. (2019). Surface ocean pH and buffer capacity: past, present and future. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-55039-4

Jiang, P., Liu, H., Piao, S., Ciais, P., Wu, X., Yin, Y., & Wang, H. (2019). Enhanced growth after extreme wetness compensates for post-drought carbon loss in dry forests. *Nature Communications*, *10*(1). https://doi.org/10.1038/s41467-018-08229-z

Juráň, S., Šigut, L., Holub, P., Fares, S., Klem, K., Grace, J., & Urban, O. (2019). Ozone flux and ozone deposition in a mountain spruce forest are modulated by sky conditions. *Science of the Total Environment*, *672*, 296–304. https://doi.org/10.1016/j.scitotenv.2019.03.491

Kadavý, J., Adamec, Z., Uherková, B., Kneifl, M., Knott, R., Kučera, A., … Drápela, K. (2019). Growth response of sessile oak and European hornbeam to traditional coppice-with-standards management. *Forests*, *10*(6), 515. https://doi.org/10.3390/f10060515

Keenan, T. F., Migliavacca, M., Papale, D., Baldocchi, D., Reichstein, M., Torn, M., & Wutzler, T. (2019). Widespread inhibition of daytime ecosystem respiration. *Nature Ecology and Evolution*, *3*(3), 407–415. https://doi.org/10.1038/s41559-019-0809-2

Kitidis, V., Shutler, J. D., Ashton, I., Warren, M., Brown, I., Findlay, H., ... Nightingale, P. D. (2019). Winter weather controls net influx of atmospheric CO2 on the north-west European shelf. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-56363-5

Kitidis, V., Shutler, J. D., Ashton, I., Warren, M., Brown, I., Findlay, H., ... Nightingale, P. D. (2019). Winter weather controls net influx of atmospheric CO2 on the north-west European shelf. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-56363-5



Kiuru, P., Ojala, A., Mammarella, I., Heiskanen, J., Erkkilä, K. M., Miettinen, H., ... Huttula, T. (2019). Applicability and consequences of the integration of alternative models for CO2 transfer velocity into a process-based lake model. *Biogeosciences*, *16*(17), 3297–3317. https://doi.org/10.5194/bg-16-3297-2019

Klosterhalfen, A., Moene, A. F., Schmidt, M., Scanlon, T. M., Vereecken, H., & Graf, A. (2019). Sensitivity analysis of a source partitioning method for H2O and CO2 fluxes based on high frequency eddy covariance data: Findings from field data and large eddy simulations. *Agricultural and Forest Meteorology*, *265*, 152–170. https://doi.org/10.1016/j.agrformet.2018.11.003

Klosterhalfen, A., Graf, A., Brüggemann, N., Drüe, C., Esser, O., González-Dugo, M. P., ... Vereecken, H. (2019). Source partitioning of H2O and CO2 fluxes based on high-frequency eddy covariance data: A comparison between study sites. *Biogeosciences*, *16*(6), 1111–1132. https://doi.org/10.5194/bg-16-1111-2019

Knox, S. H., Jackson, R. B., Poulter, B., McNicol, G., Fluet-Chouinard, E., Zhang, Z., ... Zona, D. (2019). FluXNET-CH4 synthesis activity objectives, observations, and future directions. *Bulletin of the American Meteorological Society*, *100*(12), 2607–2632. https://doi.org/10.1175/BAMS-D-18-0268.1

Kohonen, K.-M., Kolari, P., Kooijmans, L. M., Chen, H., Seibt, U., Sun, W., & Mammarella, I. (2019). Towards standardized processing of eddy covariance flux measurements of carbonyl sulfide. *Atmospheric Measurement Techniques Discussions*, 1–30. https://doi.org/10.5194/amt-2019-313

Kondo, M., Patra, P. K., Sitch, S., Friedlingstein, P., Poulter, B., Chevallier, F., ... Ziehn, T. (2019). State of the science in reconciling top-down and bottom-up approaches for terrestrial CO2 budget. *Global Change Biology*, *26*(3), 1068–1084. https://doi.org/10.1111/gcb.14917

Kooijmans, L. M. J., Sun, W., Aalto, J., Erkkilä, K. M., Maseyk, K., Seibt, U., ... Chen, H. (2019). Influences of light and humidity on carbonyl sulfide-based estimates of photosynthesis. *Proceedings of the National Academy of Sciences of the United States of America*, 116(7), 2470–2475. https://doi.org/10.1073/pnas.1807600116

Korkiakoski, M., Tuovinen, J. P., Penttilä, T., Sarkkola, S., Ojanen, P., Minkkinen, K., ... Lohila, A. (2019). Greenhouse gas and energy fluxes in a boreal peatland forest after clear-cutting. *Biogeosciences*, *16*(19), 3703–3723. https://doi.org/10.5194/bg-16-3703-2019

Kosonen, Z., Schnyder, E., Hiltbrunner, E., Thimonier, A., Schmitt, M., Seitler, E., & Thöni, L. (2019). Current atmospheric nitrogen deposition still exceeds critical loads for sensitive, semi-natural ecosystems in Switzerland. *Atmospheric Environment*, *211*, 214–225. https://doi.org/10.1016/j.atmosenv.2019.05.005

Kozii, N., Haahti, K., Tor-ngern, P., Chi, J., Hasselquist, E. M., Laudon, H., ... Hasselquist, N. (2019). Partitioning the forest water balance within a boreal catchment using sapflux, eddy covariance and process-based model. *Hydrology and Earth System Sciences Discussions*, 1–50. https://doi.org/10.5194/hess-2019-541

Kulmala, L., Pumpanen, J., Kolari, P., Dengel, S., Berninger, F., Köster, K., ... Bäck, J. (2019). Inter- and intraannual dynamics of photosynthesis differ between forest floor vegetation and tree canopy in a subarctic Scots pine stand. *Agricultural and Forest Meteorology*, 271, 1–11. https://doi.org/10.1016/j.agrformet.2019.02.029

Lagergren, F., Jönsson, A. M., Linderson, H., & Lindroth, A. (2019). Time shift between net and gross CO2 uptake and growth derived from tree rings in pine and spruce. *Trees - Structure and Function*, *33*(3), 765–776. https://doi.org/10.1007/s00468-019-01814-9

Langvall, O., & Ottosson Löfvenius, M. (2019). Long-term standardized forest phenology in Sweden: a climate change indicator. *International Journal of Biometeorology*. https://doi.org/10.1007/s00484-019-01817-8



Lebehot, A. D., Halloran, P. R., Watson, A. J., McNeall, D., Ford, D. A., Landschützer, P., ... Schuster, U. (2019). Reconciling Observation and Model Trends in North Atlantic Surface CO2. *Global Biogeochemical Cycles*, *33*(10), 1204–1222. https://doi.org/10.1029/2019GB006186

Lefèvre, N., Veleda, D., Tyaquiçã, P., Perruche, C., Diverrès, D., & Ibánhez, J. S. P. (2019). Basin-Scale Estimate of the Sea-Air CO2 Flux During the 2010 Warm Event in the Tropical North Atlantic. *Journal of Geophysical Research: Biogeosciences*, *124*(4), 973–986. https://doi.org/10.1029/2018JG004840

Leufen, L. H., & Schädler, G. (2019). Calculating the turbulent fluxes in the atmospheric surface layer with neural networks. *Geoscientific Model Development*, *12*(5), 2033–2047. https://doi.org/10.5194/gmd-12-2033-2019

Li, S., Yuan, W., Ciais, P., Viovy, N., Ito, A., Jia, B., & Zhu, D. (2019). Benchmark estimates for aboveground litterfall data derived from ecosystem models. *Environmental Research Letters*, *14*(8), 84020. https://doi.org/10.1088/1748-9326/ab2ee4

Lian, J., Bréon, F. M., Broquet, G., Scott Zaccheo, T., Dobler, J., Ramonet, M., ... Ciais, P. (2019). Analysis of temporal and spatial variability of atmospheric CO2 concentration within Paris from the GreenLITE[™] laser imaging experiment. *Atmospheric Chemistry and Physics*, *19*(22), 13809–13825. https://doi.org/10.5194/acp-19-13809-2019

Lin, M., Malyshev, S., Shevliakova, E., Paulot, F., Horowitz, L. W., Fares, S., ... Zhang, L. (2019). Sensitivity of Ozone Dry Deposition to Ecosystem-Atmosphere Interactions: A Critical Appraisal of Observations and Simulations. *Global Biogeochemical Cycles*, *33*(10), 1264–1288. https://doi.org/10.1029/2018GB006157

Liu, Y., Piao, S., Gasser, T., Ciais, P., Yang, H., Wang, H., ... Wang, T. (2019). Field-experiment constraints on the enhancement of the terrestrial carbon sink by CO2 fertilization. *Nature Geoscience*, *12*(10), 809–814. https://doi.org/10.1038/s41561-019-0436-1

Lognoul, M., Debacq, A., De Ligne, A., Dumont, B., Manise, T., Bodson, B., ... Aubinet, M. (2019). N 2 O flux short-term response to temperature and topsoil disturbance in a fertilized crop: An eddy covariance campaign. *Agricultural and Forest Meteorology*, 271, 193–206. https://doi.org/10.1016/j.agrformet.2019.02.033

Lupon, A., Denfeld, B. A., Laudon, H., Leach, J., Karlsson, J., & Sponseller, R. A. (2019). Groundwater inflows control patterns and sources of greenhouse gas emissions from streams. *Limnology and Oceanography*, *64*(4), 1545–1557. https://doi.org/10.1002/lno.11134

Macovei, V. A., Torres-Valdés, S., Hartman, S. E., Schuster, U., Moore, C. M., Brown, P. J., ... Sanders, R. J. (2019). Temporal Variability in the Nutrient Biogeochemistry of the Surface North Atlantic: 15 Years of Ship of Opportunity Data. *Global Biogeochemical Cycles*, *33*(12), 1674–1692. https://doi.org/10.1029/2018GB006132

Mäkelä, J., Knauer, J., Aurela, M., Black, A., Heimann, M., Kobayashi, H., ... Aalto, T. (2019). Parameter calibration and stomatal conductance formulation comparison for boreal forests with adaptive population importance sampler in the land surface model JSBACH. *Geoscientific Model Development*, *12*(9), 4075–4098. https://doi.org/10.5194/gmd-12-4075-2019

Mäki, M., Aaltonen, H., Heinonsalo, J., Hellén, H., Pumpanen, J., & Bäck, J. (2019). Boreal forest soil is a significant and diverse source of volatile organic compounds. *Plant and Soil*, *441*(1–2), 89–110. https://doi.org/10.1007/s11104-019-04092-z

Männistö, E., Korrensalo, A., Alekseychik, P., Mammarella, I., Peltola, O., Vesala, T., & Tuittila, E. S. (2019). Multi-year methane ebullition measurements from water and bare peat surfaces of a patterned boreal bog. *Biogeosciences*, *16*(11), 2409–2421. https://doi.org/10.5194/bg-16-2409-2019



Martinez, M. A., Woodcroft, B. J., Ignacio Espinoza, J. C., Zayed, A. A., Singleton, C. M., Boyd, J. A., ... Rich, V. I. (2019). Discovery and ecogenomic context of a global Caldiserica-related phylum active in thawing permafrost, Candidatus Cryosericota phylum nov., Ca. Cryosericia class nov., Ca. Cryosericales ord. nov., Ca. Cryosericaceae fam. nov., comprising the four species Cryosericum septentrionale gen. nov. sp. nov., Ca. C. hinesii sp. nov., Ca. C. odellii sp. nov., Ca. C. terrychapinii sp. nov. *Systematic and Applied Microbiology*, *42*(1), 54–66. https://doi.org/10.1016/j.syapm.2018.12.003

McGloin, R., Šigut, L., Fischer, M., Foltýnová, L., Chawla, S., Trnka, M., ... Marek, M. V. (2019). Available Energy Partitioning During Drought at Two Norway Spruce Forests and a European Beech Forest in Central Europe. *Journal of Geophysical Research: Atmospheres*, *124*(7), 3726–3742. https://doi.org/10.1029/2018JD029490

Monteil, G., Broquet, G., Scholze, M., Lang, M., Karstens, U., Gerbig, C., ... Walton, E. (2019). The regional EUROpean atmospheric transport inversion COMparison, EUROCOM: first results on European wide terrestrial carbon fluxes for the period 2006–2015. *Atmospheric Chemistry and Physics Discussions*, 1–40. https://doi.org/10.5194/acp-2019-1008

Monteil, G., Broquet, G., Scholze, M., Lang, M., Karstens, U., Gerbig, C., ... Walton, E. (2019). The regional EUROpean atmospheric transport inversion COMparison, EUROCOM: first results on European wide terrestrial carbon fluxes for the period 2006–2015. *Atmospheric Chemistry and Physics Discussions*, 1–40. https://doi.org/10.5194/acp-2019-1008

Morel, X., Decharme, B., Delire, C., Krinner, G., Lund, M., Hansen, B. U., & Mastepanov, M. (2019). A New Process-Based Soil Methane Scheme: Evaluation Over Arctic Field Sites With the ISBA Land Surface Model. *Journal of Advances in Modeling Earth Systems*, *11*(1), 293–326. https://doi.org/10.1029/2018MS001329

Nangini, C., Peregon, A., Ciais, P., Weddige, U., Vogel, F., Wang, J., ... Creutzig, F. (2019). A global dataset of co2 emissions and ancillary data related to emissions for 343 cities. *Scientific Data*, *6*(1). https://doi.org/10.1038/sdata.2018.280

Natali, S. M., Watts, J. D., Rogers, B. M., Potter, S., Ludwig, S. M., Selbmann, A. K., ... Zona, D. (2019). Large loss of CO2 in winter observed across the northern permafrost region. *Nature Climate Change*, *9*(11), 852–857. https://doi.org/10.1038/s41558-019-0592-8

Ney, P., Graf, A., Bogena, H., Diekkrüger, B., Drüe, C., Esser, O., ... Vereecken, H. (2019). CO2 fluxes before and after partial deforestation of a Central European spruce forest. *Agricultural and Forest Meteorology*, *274*, 61–74. https://doi.org/10.1016/j.agrformet.2019.04.009

Nijp, J. J., Metselaar, K., Limpens, J., Bartholomeus, H. M., Nilsson, M. B., Berendse, F., & van der Zee, S. E. A. T. M. (2019). High-resolution peat volume change in a northern peatland: Spatial variability, main drivers, and impact on ecohydrology. *Ecohydrology*, *12*(6). https://doi.org/10.1002/eco.2114

Nilsson, E., Rutgersson, A., Dingwell, A., Björkqvist, J. V., Pettersson, H., Axell, L., ... Strömstedt, E. (2019). Characterization of wave energy potential for the Baltic Sea with focus on the Swedish exclusive economic zone. *Energies*, *12*(5), 793. https://doi.org/10.3390/en12050793

Nisbet, E. G., Manning, M. R., Dlugokencky, E. J., Fisher, R. E., Lowry, D., Michel, S. E., ... White, J. W. C. (2019). Very Strong Atmospheric Methane Growth in the 4 Years 2014–2017: Implications for the Paris Agreement. *Global Biogeochemical Cycles*, *33*(3), 318–342. https://doi.org/10.1029/2018GB006009

Omar, A. M., Thomas, H., Olsen, A., Becker, M., Skjelvan, I., & Reverdin, G. (2019). Trends of Ocean Acidification and pCO2 in the Northern North Sea, 2003–2015. *Journal of Geophysical Research: Biogeosciences*, *124*(10), 3088–3103. https://doi.org/10.1029/2018JG004992



Palacz, A., Telszewski, M., Rehder, G., & Bittig, H. (2019). Training the Next Generation of Marine Biogeochemists. *Eos*, *100*. https://doi.org/10.1029/2019eo136334

Peaucelle, M., Bacour, C., Ciais, P., Vuichard, N., Kuppel, S., Peñuelas, J., ... Viovy, N. (2019). Covariations between plant functional traits emerge from constraining parameterization of a terrestrial biosphere model. *Global Ecology and Biogeography*, *28*(9), 1351–1365. https://doi.org/10.1111/geb.12937

Peaucelle, M., Bacour, C., Ciais, P., Vuichard, N., Kuppel, S., Peñuelas, J., ... Viovy, N. (2019). Covariations between plant functional traits emerge from constraining parameterization of a terrestrial biosphere model. *Global Ecology and Biogeography*, *28*(9), 1351–1365. https://doi.org/10.1111/geb.12937

Peaucelle, M., Ciais, P., Maignan, F., Nicolas, M., Cecchini, S., & Viovy, N. (2019). Representing explicit budburst and senescence processes for evergreen conifers in global models. *Agricultural and Forest Meteorology*, *266–267*, 97–108. https://doi.org/10.1016/j.agrformet.2018.12.008

Peaucelle, M., Janssens, I. A., Stocker, B. D., Descals Ferrando, A., Fu, Y. H., Molowny-Horas, R., ... Peñuelas, J. (2019). Spatial variance of spring phenology in temperate deciduous forests is constrained by background climatic conditions. *Nature Communications*, *10*(1). https://doi.org/10.1038/s41467-019-13365-1

Peltola, O., Vesala, T., Gao, Y., Räty, O., Alekseychik, P., Aurela, M., ... Aalto, T. (2019). Monthly gridded data product of northern wetland methane emissions based on upscaling eddy covariance observations. *Earth System Science Data*, *11*(3), 1263–1289. https://doi.org/10.5194/essd-11-1263-2019

Pierrot, D., Steinhoff, T., & Oceanographic, A. (2019). Installation of Autonomous Underway pCO2 Instruments onboard Ships of Opportunity. *NOAA Technical Report*, p. 31. https://doi.org/10.25923/ffz6-0x48

Pisso, I., Sollum, E., Grythe, H., Kristiansen, N. I., Cassiani, M., Eckhardt, S., ... Stohl, A. (2019). The Lagrangian particle dispersion model FLEXPART version 10.4. *Geoscientific Model Development*, *12*(12), 4955–4997. https://doi.org/10.5194/gmd-12-4955-2019

Proietti, C., Anav, A., Vitale, M., Fares, S., Fornasier, M. F., Screpanti, A., ... De Marco, A. (2019). A new wetness index to evaluate the soil water availability influence on gross primary production of european forests. *Climate*, *7*(3), 42. https://doi.org/10.3390/cli7030042

Puche, N., Senapati, N., Flechard, C. R., Klumpp, K., Kirschbaum, M. U. F., & Chabbi, A. (2019). Modeling carbon and water fluxes of managed grasslands: Comparing flux variability and net carbon budgets between grazed and mowed systems. *Agronomy*, *9*(4), 183. https://doi.org/10.3390/agronomy9040183

Räsänen, A., Aurela, M., Juutinen, S., Kumpula, T., Lohila, A., Penttilä, T., & Virtanen, T. (2019). Detecting northern peatland vegetation patterns at ultra-high spatial resolution. *Remote Sensing in Ecology and Conservation*. https://doi.org/10.1002/rse2.140

Räsänen, A., Juutinen, S., Aurela, M., & Virtanen, T. (2019). Predicting aboveground biomass in Arctic landscapes using very high spatial resolution satellite imagery and field sampling. *International Journal of Remote Sensing*, *40*(3), 1175–1199. https://doi.org/10.1080/01431161.2018.1524176

Räsänen, A., Juutinen, S., Tuittila, E. S., Aurela, M., & Virtanen, T. (2019). Comparing ultra-high spatial resolution remote-sensing methods in mapping peatland vegetation. *Journal of Vegetation Science*, *30*(5), 1016–1026. https://doi.org/10.1111/jvs.12769

Réjou-Méchain, M., Barbier, N., Couteron, P., Ploton, P., Vincent, G., Herold, M., ... Pélissier, R. (2019). Upscaling Forest Biomass from Field to Satellite Measurements: Sources of Errors and Ways to Reduce Them. *Surveys in Geophysics*, *40*(4), 881–911. https://doi.org/10.1007/s10712-019-09532-0



Rineau, F., Malina, R., Beenaerts, N., Arnauts, N., Bardgett, R. D., Berg, M. P., ... Vangronsveld, J. (2019). Towards more predictive and interdisciplinary climate change ecosystem experiments. *Nature Climate Change*, *9*(11), 809–816. https://doi.org/10.1038/s41558-019-0609-3

Rosíková, J., Darenova, E., Kučera, A., Volařík, D., & Vranová, V. (2019). Effect of different dolomitic limestone dosages on soil respiration in a mid-altitudinal Norway spruce stand. *IForest*, *12*(4), 357–365. https://doi.org/10.3832/ifor2894-012

Šálek, M., & Szabó-Takács, B. (2019). Comparison of SAFNWC/MSG satellite cloud type with Vaisala CL51 ceilometer-detected cloud base layer using the sky condition algorithm and Vaisala BL-View software. *Atmosphere*, *10*(6), 316. https://doi.org/10.3390/atmos10060316

Schepaschenko, D., Chave, J., Phillips, O. L., Lewis, S. L., Davies, S. J., Réjou-Méchain, M., ... Zo-Bi, I. C. (2019). The Forest Observation System, building a global reference dataset for remote sensing of forest biomass. *Scientific Data*, *6*(1), 198. https://doi.org/10.1038/s41597-019-0196-1

Silva, B. J., Gaspar, F. L., Tyaquiçã, P., Lefèvre, N., & Flores Montes, M. J. (2019). Carbon chemistry variability around a tropical archipelago. *Marine and Freshwater Research*, *70*(6), 767–780. https://doi.org/10.1071/MF18011

Sofie Lansø, A., Luke Smallman, T., Heile Christensen, J., Williams, M., Pilegaard, K., Sorensen, L. L., & Geels, C. (2019). Simulating the atmospheric CO2 concentration across the heterogeneous landscape of Denmark using a coupled atmosphere-biosphere mesoscale model system. *Biogeosciences*, *16*(7), 1505–1524. https://doi.org/10.5194/bg-16-1505-2019

Song, J., Wan, S., Piao, S., Hui, D., Hovenden, M. J., Ciais, P., ... Ru, J. (2019). Elevated CO 2 does not stimulate carbon sink in a semi-arid grassland. *Ecology Letters*, *22*(3), 458–468. https://doi.org/10.1111/ele.13202

Soussana, J. F., Lutfalla, S., Ehrhardt, F., Rosenstock, T., Lamanna, C., Havlík, P., ... Lal, R. (2019). Matching policy and science: Rationale for the '4 per 1000 - soils for food security and climate' initiative. *Soil and Tillage Research*, *188*, 3–15. https://doi.org/10.1016/j.still.2017.12.002

Spielmann, F. M., Wohlfahrt, G., Hammerle, A., Kitz, F., Migliavacca, M., Alberti, G., ... Delle Vedove, G. (2019). Gross Primary Productivity of Four European Ecosystems Constrained by Joint CO2 and COS Flux Measurements. *Geophysical Research Letters*, *46*(10), 5284–5293. https://doi.org/10.1029/2019GL082006

Steinhoff, T., Gkritzalis, T., Lauvset, S. K., Jones, S., Schuster, U., Olsen, A., ... Watson, A. (2019). Constraining the Oceanic Uptake and Fluxes of Greenhouse Gases by Building an Ocean Network of Certified Stations: The Ocean Component of the Integrated Carbon Observation System, ICOS-Oceans. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/fmars.2019.00544

Stella, P., Loubet, B., de Berranger, C., Charrier, X., Ceschia, E., Gerosa, G., ... Ciuraru, R. (2019). Soil ozone deposition: Dependence of soil resistance to soil texture. *Atmospheric Environment*, *199*, 202–209. https://doi.org/10.1016/j.atmosenv.2018.11.036

Stoy, P. C., El-Madany, T. S., Fisher, J. B., Gentine, P., Gerken, T., Good, S. P., ... Wolf, S. (2019). Reviews and syntheses: Turning the challenges of partitioning ecosystem evaporation and transpiration into opportunities. *Biogeosciences*, *16*(19), 3747–3775. https://doi.org/10.5194/bg-16-3747-2019

Su, Y., Liu, L., Wu, J., Chen, X., Shang, J., Ciais, P., ... Huang, N. (2019). Quantifying the biophysical effects of forests on local air temperature using a novel three-layered land surface energy balance model. *Environment International*, *132*, 105080. https://doi.org/10.1016/j.envint.2019.105080

Super, I., Denier van der Gon, H. A., Dellaert, S. N., & Peters, W. (2019). Optimizing a dynamic fossil fuel CO2 emission model with CTDAS (v1.0) for an urban area using atmospheric observations of CO2, CO, NOx, and SO2. *Geoscientific Model Development Discussions*, 1–38. https://doi.org/10.5194/gmd-2019-283



Svensson, N., Bergström, H., Rutgersson, A., & Sahlée, E. (2019). Modification of the Baltic Sea wind field by land-sea interaction. *Wind Energy*, *22*(6), 764–779. https://doi.org/10.1002/we.2320

Tanhua, T., Pouliquen, S., Hausman, J., O'Brien, K. M., Bricher, P., Bruin, T. de, ... Zhao, Z. (2019). Ocean FAIR data services. *Frontiers in Marine Science*, *6*(JUL). https://doi.org/10.3389/fmars.2019.00440

Tebaldini, S., Ho Tong Minh, D., Mariotti d'Alessandro, M., Villard, L., Le Toan, T., & Chave, J. (2019). The Status of Technologies to Measure Forest Biomass and Structural Properties: State of the Art in SAR Tomography of Tropical Forests. *Surveys in Geophysics*, *40*(4), 779–801. https://doi.org/10.1007/s10712-019-09539-7

Tian, H., Yang, J., Xu, R., Lu, C., Canadell, J. G., Davidson, E. A., ... Zhang, B. (2019). Global soil nitrous oxide emissions since the preindustrial era estimated by an ensemble of terrestrial biosphere models: Magnitude, attribution, and uncertainty. *Global Change Biology*, *25*(2), 640–659. https://doi.org/10.1111/gcb.14514

Tiralla, N., Panferov, O., Kreilein, H., Olchev, A., Ali, A. A., & Knohl, A. (2019). Quantification of leaf emisivities of forest species: Effects on modeled energy and matter fluxes in forest ecosystems. *Geography, Environment, Sustainability*, *12*(2), 245–258. https://doi.org/10.24057/2071-9388-2018-86

Tsuruta, A., Aalto, T., Backman, L., Krol, M. C., Peters, W., Lienert, S., ... Gomez-Pelaez, A. J. (2019). Methane budget estimates in Finland from the CarbonTracker Europe-CH4 data assimilation system. *Tellus, Series B: Chemical and Physical Meteorology*, *71*(1), 1–20. https://doi.org/10.1080/16000889.2018.1565030

Tuovinen, J. P., Aurela, M., Hatakka, J., Räsänen, A., Virtanen, T., Mikola, J., ... Laurila, T. (2019). Interpreting eddy covariance data from heterogeneous Siberian tundra: Land-cover-specific methane fluxes and spatial representativeness. *Biogeosciences*, *16*(2), 255–274. https://doi.org/10.5194/bg-16-255-2019

Vernet, M., Geibert, W., Hoppema, M., Brown, P. J., Haas, C., Hellmer, H. H., ... Verdy, A. (2019). The Weddell Gyre, Southern Ocean: Present Knowledge and Future Challenges. *Reviews of Geophysics*, *57*(3), 623–708. https://doi.org/10.1029/2018RG000604

Vincent-Barbaroux, C., Berveiller, D., Lelarge-Trouverie, C., Maia, R., Máguas, C., Pereira, J., ... Damesin, C. (2019). Carbon-use strategies in stem radial growth of two oak species, one Temperate deciduous and one Mediterranean evergreen: what can be inferred from seasonal variations in the δ 13C of the current year ring? *Tree Physiology*, *39*(8), 1329–1341. https://doi.org/10.1093/treephys/tpz043

Vitale, D., Bilancia, M., & Papale, D. (2019). A multiple imputation strategy for eddy covariance data. *Journal of Environmental Informatics*, *34*(2), 68–87. https://doi.org/10.3808/jei.201800391

Vitale, D., Bilancia, M., & Papale, D. (2019). Modelling random uncertainty of eddy covariance flux measurements. *Stochastic Environmental Research and Risk Assessment*, *33*(3), 725–746. https://doi.org/10.1007/s00477-019-01664-4

Vogel, F. R., Frey, M., Staufer, J., Hase, F., Broquet, G., Xueref-Remy, I., ... Orphal, J. (2019). XCO2 in an emission hot-spot region: The COCCON Paris campaign 2015. *Atmospheric Chemistry and Physics*, *19*(5), 3271–3285. https://doi.org/10.5194/acp-19-3271-2019

Voigt, C., Marushchak, M. E., Mastepanov, M., Lamprecht, R. E., Christensen, T. R., Dorodnikov, M., ... Biasi, C. (2019). Ecosystem carbon response of an Arctic peatland to simulated permafrost thaw. *Global Change Biology*, *25*(5), 1746–1764. https://doi.org/10.1111/gcb.14574

Wang, S., Garcia, M., Bauer-Gottwein, P., Jakobsen, J., Zarco-Tejada, P. J., Bandini, F., ... Ibrom, A. (2019). High spatial resolution monitoring land surface energy, water and CO2 fluxes from an Unmanned Aerial System. *Remote Sensing of Environment*, *229*, 14–31. https://doi.org/10.1016/j.rse.2019.03.040



Wang, Y., Ciais, P., Broquet, G., Bréon, F. M., Oda, T., Lespinas, F., ... Su, Y. (2019). A global map of emission clumps for future monitoring of fossil fuel CO2 emissions from space. *Earth System Science Data*, *11*(2), 687–703. https://doi.org/10.5194/essd-11-687-2019

Wanninkhof, R., Pickers, P. A., Omar, A. M., Sutton, A., Murata, A., Olsen, A., ... Schuster, U. (2019). A surface ocean CO2 reference network, SOCONET and associated marine boundary layer CO2 measurements. *Frontiers in Marine Science*, *6*(JUL). https://doi.org/10.3389/fmars.2019.00400

Wanninkhof, R., Pickers, P. A., Omar, A. M., Sutton, A., Murata, A., Olsen, A., ... Schuster, U. (2019). A surface ocean CO2 reference network, SOCONET and associated marine boundary layer CO2 measurements. *Frontiers in Marine Science*, *6*(JUL). https://doi.org/10.3389/fmars.2019.00400

White, E. D., Rigby, M., Lunt, M. F., Luke Smallman, T., Comyn-Platt, E., Manning, A. J., ... Palmer, P. I. (2019). Quantifying the UK's carbon dioxide flux: An atmospheric inverse modelling approach using a regional measurement network. *Atmospheric Chemistry and Physics*, *19*(7), 4345–4365. https://doi.org/10.5194/acp-19-4345-2019

Xia, J., Yuan, W., Lienert, S., Joos, F., Ciais, P., Viovy, N., ... Tian, X. (2019). Global Patterns in Net Primary Production Allocation Regulated by Environmental Conditions and Forest Stand Age: A Model-Data Comparison. *Journal of Geophysical Research: Biogeosciences*, *124*(7), 2039–2059. https://doi.org/10.1029/2018JG004777

Yuan, W., Zheng, Y., Piao, S., Ciais, P., Lombardozzi, D., Wang, Y., ... Yang, S. (2019). Increased atmospheric vapor pressure deficit reduces global vegetation growth. *Science Advances*, *5*(8), eaax1396. https://doi.org/10.1126/sciadv.aax1396

Zeeman, M. J., Shupe, H., Baessler, C., & Ruehr, N. K. (2019). Productivity and vegetation structure of three differently managed temperate grasslands. *Agriculture, Ecosystems and Environment, 270–271*, 129–148. https://doi.org/10.1016/j.agee.2018.10.003

Zellweger, C., Steinbrecher, R., Laurent, O., Lee, H., Kim, S., Emmenegger, L., ... Buchmann, B. (2019). Recent advances in measurement techniques for atmospheric carbon monoxide and nitrous oxide observations. *Atmospheric Measurement Techniques*, *12*(11), 5863–5878. https://doi.org/10.5194/amt-12-5863-2019

Zhang, W., Jansson, P. E., Sigsgaard, C., McConnell, A., Jammet, M. M., Westergaard-Nielsen, A., ... Elberling, B. (2019). Model-data fusion to assess year-round CO2 fluxes for an arctic heath ecosystem in West Greenland (69°N). *Agricultural and Forest Meteorology*, *272–273*, 176–186. https://doi.org/10.1016/j.agrformet.2019.02.021

Zhang, Y., Goll, D., Bastos, A., Balkanski, Y., Boucher, O., Cescatti, A., ... Ciais, P. (2019). Increased Global Land Carbon Sink Due to Aerosol-Induced Cooling. *Global Biogeochemical Cycles*, *33*(3), 439–457. https://doi.org/10.1029/2018GB006051

Zheng, B., Chevallier, F., Yin, Y., Ciais, P., Fortems-Cheiney, A., Deeter, M. N., ... Zhao, Y. (2019). Global atmospheric carbon monoxide budget 2000-2017 inferred from multi-species atmospheric inversions. *Earth System Science Data*, *11*(3), 1411–1436. https://doi.org/10.5194/essd-11-1411-2019

Zhou, M., Langerock, B., Sha, M. K., Kumps, N., Hermans, C., Petri, C., ... De Mazière, M. (2019). Retrieval of atmospheric CH4 vertical information from ground-based FTS near-infrared spectra. *Atmospheric Measurement Techniques*, *12*(11), 6125–6141. https://doi.org/10.5194/amt-12-6125-2019

Zhou, M., Langerock, B., Vigouroux, C., Kumar Sha, M., Hermans, C., Metzger, J. M., ... De Mazière, M. (2019). TCCON and NDACC XCO measurements: Difference, discussion and application. *Atmospheric Measurement Techniques*, *12*(11), 5979–5995. https://doi.org/10.5194/amt-12-5979-2019



Zhu, P., Zhuang, Q., Welp, L., Ciais, P., Heimann, M., Peng, B., ... Keenan, T. F. (2019). Recent warming has resulted in smaller gains in net carbon uptake in northern high latitudes. *Journal of Climate*, *32*(18), 5849–5863. https://doi.org/10.1175/JCLI-D-18-0653.1

Ziegler, C., Coste, S., Stahl, C., Delzon, S., Levionnois, S., Cazal, J., ... Bonal, D. (2019). Large hydraulic safety margins protect Neotropical canopy rainforest tree species against hydraulic failure during drought. *Annals of Forest Science*, *76*(4). https://doi.org/10.1007/s13595-019-0905-0

Ziemblińska, K., Urbaniak, M., Dukat, P., & Olejnik, J. (2019). Measurements of co2 fluxes at non-ideal eddy covariance sites. *Journal of Visualized Experiments*, *2019*(148). https://doi.org/10.3791/59525

Zöll, U., Lucas-Moffat, A. M., Wintjen, P., Schrader, F., Beudert, B., & Brümmer, C. (2019). Is the biosphereatmosphere exchange of total reactive nitrogen above forest driven by the same factors as carbon dioxide? An analysis using artificial neural networks. *Atmospheric Environment*, *206*, 108–118. https://doi.org/10.1016/j.atmosenv.2019.02.042

Other materials

- ICOS Handbook 2019, ISBN 978-952-94-1950-0
- ICOS Strategy
- ICOS Ocean Thematic Centre brochure
- Leaflets, flyers and digital materials for events to promote ICOS