

ICOS RI Annual Report 2020

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ICOS

Integrated
Carbon
Observation
System

Foreword by the Director General Werner Kutsch

This annual report is a very special one. 2020 will be remembered as the COVID-19 pandemic year. The pandemic has shaken our lives, the economies and the behaviour globally. There is no question that it also affected ICOS RI severely. There is one important message to be mentioned first: we know that some people within the ICOS community have been suffered from a COVID-19 infection but I am not aware of any lethal case. This is a big relief. Nevertheless, the pandemic-related confinements brought multiple challenges to our research infrastructure, the biggest ones perhaps being the partly broken measurement and maintenance procedures and the complete loss of direct communication in face-to-face meetings.

We managed to tackle both challenges. Many work routines were adapted to the conditions and the data were partly delayed but not lost, except for some very few exceptions, which shows the robustness of the ICOS stations. Multiple meetings, including the 4th ICOS Science Conference, were transferred to the virtual space. Also, the very first ICOS Evaluation was conducted completely by virtual meetings.

All these caused extra efforts which were taken bravely by the ICOS community and rewarded by the excellent results. The positive feedback on the Science Conference has been overwhelming and the overall result of the Evaluation was a clear 'excellent'. In addition, ICOS made substantial contributions to explain and observe the impact of the confinement to greenhouse gas concentrations and fluxes.

As a consequence of the specific challenges of 2020, this report has a slightly different structure than the previous years' reports, with more emphasis in cross-domain activities and more concise reports of each facility and partner.

While looking forward to meet many of you in person again, I want to congratulate and thank you for the efforts in 2020.

Dr. Werner L Kutsch, Director General

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2020 Highlights of ICOS Research Infrastructure

The First ICOS RI 5-year Evaluation in 2020

Since this was the first time a distributed Research Infrastructure was evaluated, the journey was quite challenging, but rewarding. The Head Office and the Evaluation Committee developed the method as the evaluation progressed and now certain phases and parts can be described.

The Evaluation concept was divided into five categories (Management, Financial Management, Internal Engagement and Structure, ICOS Data and User Expectations, International Cooperation). The data collection phase included two parts: gathering relevant documents and executing surveys. The Head Office collected documentation regarding all five categories and created survey questions in cooperation with the Evaluation Committee. The survey was sent to several groups connected to ICOS RI, both within and outside the organisation. The Head Office provided category reports describing their current status and the development in the last five years, occasionally projecting into the future, based on the documentation and the survey results.

Another important phase of the Evaluation was the creation of KPIs for ICOS RI. The ICOS Head Office staff and the Evaluation Committee created them in cooperation. A category description, the status of these KPIs and the survey results were presented in the Final Evaluation Meeting by the Evaluation Committee. Relevant groups from the ICOS organisation and stakeholders were invited to follow and discuss the category sessions. The meeting concluded with a feedback session from the Evaluation Committee to the General Assembly Chairs and the Director General.

After the meeting, two reports were prepared based on the materials and reports assembled: The Head Office wrote the Evidence report and to assure the integrity of the Evaluation Committee, the Committee members provided a separate report with their conclusions and recommendations. These reports were discussed in the 13th Extraordinary General Assembly 25 March 2021.

Coping with the COVID19 pandemic and lockdown effects to operational activities

Spreading of COVID19 in Europe affected activities in all European countries from March 2020 onwards. European countries tried to slow down the spreading of the virus by social distancing: limiting how many people could be in same space simultaneously. In most countries, teaching in schools and universities became distant learning, office work became remote work.

At the ICOS measurement stations and laboratories these limitations slowed down some activities but did not prevent the work from being done. Especially maintenance and support of instruments manufacturers was much slower than in normal times.

During the initial lockdown (spring 2020) It was more challenging to visit stations and in some cases not possible at all. saying that the overall situation was positive and stations kept going. Face to face meetings were not possible and all activities / meetings were now virtual. These presented some challenges but also introduced some flexibility and at the same time reduced the carbon footprint of individuals (reduced/no travelling).

Due to the Covid, the collaboration was done mainly through online meetings. Even though in the beginning all enjoyed the saved travel time, and attendance to e.g. MSA meetings was larger than ever before, during the year the number of such meetings grew to be a considerable burden especially for employees involved in several projects, evaluation, and in the management of different bodies of the ICOS RI.

Scientific activities related to COVID19 pandemic

The Covid-19 related restrictions forced many of us to stay at home. This reduced road traffic and economic activities particularly in cities and urban areas where the majority of people live. Consequently, this also cut down human-induced carbon dioxide (CO₂) emissions to the atmosphere. Already in May 2020, ICOS released **results of a scientific study that shows a large reduction in carbon dioxide (CO₂) emissions in seven European cities during the lockdown caused by the Covid-19 virus. The study was conducted by ICOS ecosystem scientists together with colleagues around Europe.**

Although this reduction was not strong enough to be globally visible in the atmosphere, the changes in emissions could be observed at local scale. The study showed that the lockdown reduced carbon dioxide emissions at all cities participating the study. "The reductions range from 8% in a highly vegetated urban area of Berlin, Germany, to 75% in the city centre of Heraklion in Greece".

The European cities included in the study were Basel in Switzerland, Berlin in Germany, Florence and Pesaro in Italy, Helsinki in Finland, Heraklion in Greece and London in the UK. The size of reduction varied due to the characteristics of the sampled areas and the stringency of the lockdown restrictions in place. In all cities, there was a clear temporal connection with the restrictions and the emission reduction.

The Covid-19-related change in the carbon dioxide content of the atmosphere is within the uncertainty caused by the natural variability of the CO₂ budget, and hence not globally visible in the atmosphere. However, it adds up over time and increases with the duration of the shutdown.

Papale D. et al. (2020) Clear evidence of reduction in urban CO₂ emissions as a result of COVID-19 lockdown across Europe

Kutsch, Vermeulen and Karstens (2020): Finding a hair in the swimming pool: The signal of changed fossil emissions in the atmosphere

Science conference 2020

The 4th ICOS Science conference was organized 15th to 17th of September 2020. It was planned to be held in Utrecht, Netherlands, but due to COVID-related restrictions, it was transferred to be held online. The venue reserved for Utrecht would have been capable to take up to 400 participants. We were pleasantly surprised when the virtual ICOS Science conference attracted more than 1000 attendees. This is a huge addition compared to 300 participants present in the previous conference held in Prague 2018.

The feedback was positive and generally encouraging to include some of the virtual elements in the future ICOS Conferences even when pandemic situation allows travelling. This wish for organizing a hybrid conference in the future does not come without any additional costs, but it clearly showed that virtual conference can indeed be much more than another lengthy video meeting. Hence, ICOS was again seen as an example for successful organisation as setting the standard of virtual conferences. We had 85 poster presentations and 106 oral presentations: 16 plenary talks and the rest divided into 18 parallel sessions. The active unique visitor count in the plenary hall was 1334. This invigorated 411 chat messages.

The abstract submission was slightly different from previous conferences. The double-anonymous review process used herein was considered as one of the key elements of this success. For this we owe our greatest gratitude to the session conveners. These conveners wrote session descriptions, which were modified into broader context according to advice received from the programme committee. After the abstract submission the session conveners were responsible for the abstract evaluation. Hence, these abstracts had gone through a very careful peer review, some had been evaluated by as many as

eight independent examiners. This process allowed several junior scientists, and even PhD students as speakers in plenary sessions as well as prominent esteemed international leading experts of their field and formed a very interesting programme.

The successful operations of a virtual conference required external expert help of a professional virtual event organizer, virtual event platform (ProspectumLive) and technicians. Running three parallel sessions smoothly throughout the conference required also investment into studio teams. Uploading of presentations two weeks in advance was necessary for practical reasons and it also allowed voluntary practise sessions to be organized for all speakers before the conference. Compared to physical conference, the timing of parallel sessions succeeded with highest precision that enabled audience to switch between the sessions without missing any of the beginnings nor causing any disturbance to the speaker or delays in the programme.

A dedicated chat in every session was found useful and essential element in our conference. This could easily be implemented in any physical conference as well. The chat helped the chair to select questions based on content. Those questions which were not answered during the online broadcasting, were answered afterwards in the chat – either by the presenter or other community members. Everybody was getting an equal opportunity to ask their question or making their comment and thus getting their voice to be heard.

The Eventos Mobile app was another new practical application and improvement that was for the first time in use at the ICOS Science conference 2020. This addition was also considered a useful tool, preferred to be used again in the future conferences if the finances allows it. Yet, poster sessions are among a top priority in things to improve in the future, in case of virtual conference. Preparing a poster presentation and uploading them into a virtual platform required as much effort as any oral presentation, but they didn't receive as much attention nor interaction as orals. Organisers should seeks possibilities how this can be endorsed in the future conferences, if using a virtual or hybrid model.

Recording all sessions and having them available online for a limited time allowed participants a chance to listen to talks from parallel sessions afterwards, and encouraged participation across time zones. Having the recordings available for two weeks received positive feedback, but if the time could prolonged, it would even further enhance the visibility of our science. Hence we should encourage authors for approving a prolonged time to view these recordings in the future.

Another benefit of a virtual conference was that it allowed participation even without any own presentation, because there were no travel costs. The ICOS Science conference 2020 was also free of charge and without any registration fee, which is in accordance with EU Open Science Policy. This encouraged student - and worldwide participation.

Drought special issue

A special issue of *Philosophical Transactions B* was written and edited by the ICOS community, with the ICOS Thematic Centres strongly involved in the data processing. It consisted of 17 studies representing work of over 200 ICOS scientists showing how natural ecosystems, managed grassland and crops in Europe responded to extremely dry conditions during summer 2018. These conditions are expected to occur more frequently in the future. Many of the studies found that on the European scale, the forests protected themselves by reducing their evaporation and growth, leading to decreased uptake of carbon dioxide. Carbon sinks decreased in general by 18% according to a study covering 56 sites with agricultural areas showing the largest impact on carbon sink reduction. It was further shown that heat release into the atmosphere was on average significantly higher than in previous years almost across all ecosystem types. The reason was that increased solar radiation did not lead to higher evapotranspiration and thus cooling of the atmosphere due to the shortage of plant available water.

The dry conditions even turned some ecosystems from sinks into sources. However, rewetted peatlands seemed to survive better e.g. due to new plant growth. This is good news since rewetting peatlands is one of the means widely used to mitigate the consequences of climate change.

Further, these studies show that the response of the vegetation to an extremely dry summer is strongly dependent on the previous spring and even winter conditions. In some parts of Europe, winter 2018 was wet, leaving a lot of soil moisture in the ground, while spring was sunny and came early - this caused the vegetation to grow more than average in spring, taking up more carbon from the atmosphere than usual. In some places, this early spring growth was enough to offset the reduction of carbon uptake later in summer.

RINGO Highlights

RINGO, 'Readiness of ICOS for Necessities of Integrated Global Observations' (2017–2020) was a 4-year H2020 project with a total budget of 4,719,680.00 euros. Coordinated by the Head Office, RINGO had 43 partners in 19 countries and consisted of 5 work packages with specific emphasis on the further development of the readiness of ICOS RI to foster its sustainability. As highlights we can mention the following:

Increasing the Impact of ICOS

The results from the strategy document delivered at the end of 2019 were successfully integrated and used after some minor modifications at the ICOS Evaluation process carried out during 2020.

Improved readiness to provide information on fossil fuel emissions

The questions of how to optimise the $^{14}\text{CO}_2$ sampling strategy in ICOS by serving two different purposes was successfully completed. First, to improve the experimental ability to separate fossil fuel CO_2 contributions from biogenic signals in urban emission plumes, and second to provide an optimised monitoring network that enables atmospheric inverse modelling frameworks to estimate national fossil fuel CO_2 emissions with high confidence.

Enhancing the bridge between ICOS RI and satellite observations

Since wood density is key to convert tree volume to above ground biomass, a sensitivity analysis was performed to determine the variability in wood density at three heights for four different species. A revised scientific-technical protocol for standardized biomass observations in ICOS using ground LIDAR was completed.

During the RINGO project a concept for the integration of the European TCCON stations into ICOS has been developed. The concept document includes the associated costs of a potential integration of the European TCCON stations into ICOS and related costs for the stations and the central facility. It has been disseminated and discussed with selected national funding agencies. AirCore profiles for the TCCON calibration as well as the development of a methane profile retrieval from TCCON spectra enhance the link between in situ and the remote sensing measurements of GHGs.

Developing ICOS RI readiness to provide information on land-ocean carbon fluxes

The export of carbon (C) from land to sea via the Land-Ocean Aquatic Continuum (LOAC) is a substantial component of the global C cycle, with the lateral transport of C through aquatic environments stimulating a vertical exchange of gaseous C between the LOAC and the atmosphere. Aquatic environments are highly dynamic, and subject to a multitude of environmental pressures linked to

global climate change and human activities. In order to understand the effect of these pressures on the global C cycle, a high-quality monitoring network is required to resolve spatial and temporal variability. This report provides guidance on the requirements for such a network at pan-European scale, including the extent to which monitoring might be integrated within existing infrastructure.

We discuss the transport of terrigenous C along the LOAC (land – stream – river – estuary – coastal zone – ocean), and consider additional linked environments such as groundwater, lakes, wetlands, and constructed water bodies. We outline the requirements for monitoring lateral and vertical C fluxes associated with each of these environments, and suggest a blueprint by which monitoring of these fluxes may be achieved.

The requirements of the proposed monitoring programme are outlined as follows: (1) regular monitoring of the lateral movement of C through the LOAC, conducted at broad spatial scale by national agencies under the guidance of the European Environment Agency (EEA), and according to site selection and methodological criteria provisionally set forth in this report; (2) regular monitoring of the vertical movement of C between the LOAC and the atmosphere, conducted at key 'super-sites' and administered by the ICOS and other research infrastructure and institutes; and (3) focussed studies to understand the processes that act upon C fluxes along the LOAC, conducted by research centres and driven by targeted research calls. Investment in autonomous systems is advised, with examples of existing technologies provided.

As a next step, the WP recommends the formation of a new LOAC Thematic Centre (LTC) to oversee a preparatory phase, with the goal of initiating a pan-European land-ocean C monitoring network within 10 years. This timeline is short, but is considered necessary given the significance of these fluxes to large-scale C budgeting and the current lack of consistent data sets.

Director general and head office

Progress in the regular tasks

General Assembly coordination

The General Assembly meetings were held virtually due to the Covid-19 pandemic. In the spring meeting, the General Assembly elected a new member for the Scientific Advisory Board. The Evaluation Committee Chair Andrew Harrison gave a status report of the ICOS Evaluation in progress. The ICOS ERIC legal entity books 2019 were closed, and the financial statements for 2019 were approved. The Director General was subsequently discharged of liability. Dr. habil. Werner Leo Kutsch was appointed for a second five-year term as the Director General of ICOS (starting 1.1.2021).

The autumn meeting was held over two days. Spain's adhesion to ICOS was approved from January 1st, 2021. Petteri Kauppinen was re-elected as the Vice Chair for 2021-2022. The General Assembly re-elected Silvia Peppoloni, Per Sandin, and Meri Vannas unanimously to be members of the Ethical Advisory Board for 2021-2023. Updated ICOS Financial Rules and a new format of Annex 2 of the ICOS Statutes were approved. The Evaluation Committee Chair presented an interim report of ICOS Evaluation.

RI Committee management

The RI Committee, formed by representatives from the Head Office, Carbon Portal, Central facilities and Monitoring Station Assemblies, had a 2-day face-to-face meeting in March in Poznan Poland. Head office hosted monthly teleconferences as well as a 3-day online workshop in October replacing the usual face-to-face meeting. In addition, RI COM had a joint meeting with financial committee to clarify the issue of unspent funds in preparation for the autumn GA meeting.

Support for Scientific and Ethical Advisory Boards

The science advisory board meeting in November was held online and split to two days to accommodate all the various timezones from Finland to West coast USA. The Ethical Advisory Board did not have any meetings, but a meeting was scheduled at the beginning of the 2021.

In their report, SAB has highly commended the strides ICOS RI has taken, as the value of ICOS network and data is increasing. ICOS's mission and vision as a 'reference' network' in providing a calibrated long-term benchmark for terrestrial, ecosystem, atmospheric, ocean, and fossil fuel observations has become clearer over the last couple of years. The SAB also commended ICOS's role in, and support for, analyses exploring the 2018 European drought: The special issue resulting from that effort is a great accomplishment. The rapid scientific progress in these analyses was enabled both by the availability of ICOS data, and by the ease of access to ICOS and other data made possible by the Carbon Portal. This is a remarkable success story in reaching the broader scientific community and stakeholders and should continue to be highlighted.

The SAB is excited about the urban observatory proposal (aka PAUL) and also supports the development of the Marie Skłodowska-Curie training proposal, as it will help expand opportunities and make science more inclusive. Within the context of the COVID-19 pandemic, SAB also appreciates the remarkable job done by ICOS is switching to an online format. As the online participation skyrocketed, especially in the ICOS Science Conference, SAB recommends to examine how to leverage the success of virtual meetings (easy attendance, less expensive) while retaining the benefits of physical meetings.

Financial management of ICOS ERIC

The year 2020 was the first year of the second 5-year period of ICOS ERIC. The proposal for the half of Finnish Host Contribution was submitted to the Academy of Finland in August 2020. The decision received in December 2020 and the funding received did not change. The Finnish Institute of the Meteorology and France followed the decision of the Academy of Finland and did not increase the Host Contributions. Two Horizon 2020 projects ended during the year. ICOS ERIC was the consortium leader in one of the projects. Two new projects funds were received.

Overall financial management of ICOS RI

ICOS ERIC Financial Committee had two meetings during the year and one joint meeting with the RICOM. The Chair of the Financial Committee presented the committee's report at the Autumn General Assembly meeting on the financial situation of ICOS ERIC. The committee has discussed mostly about the updates of the Financial Rules and the unspent funds. The discussion on the size and follow-up reporting of unspent funds was concluded, but the discussion on a common reserve fund will continue. During the last latest three year the Head Office has developed systematic monitoring for project funding.

Human resources management for ICOS ERIC

During the year, 9 fixed-term contracts were changed to be valid until further notice and two position was announced to be opened. The three positions were declared open and filled. A communications assistant assigned a person to replace a part-time employee. During the review the year completed the Head Office Early Support Model, which helps supervisors support employees to cope with their work. This model provides guidance on early intervention and is mandatory under the Finnish Occupational Safety and Health Act. All supervisor have trained to use this model by Occupational Health Psychologist.

The following personnel was employed by ICOS ERIC: by the end of the 2020:

- Director General (Werner Kutsch)
- Director of Carbon Portal (Alex Vermeulen)
- Head of Unit I 'Administration' (Anne Malm)
- Head of Unit II 'Operations' (Elena Saltikoff)
- Head of Unit III 'Strategy & International Cooperation' (Emmanuel Salmon)
- Head of Unit IV III 'Communications' (Katri Ahlgren)
- Science Integration Officer, Unit II (Sindu Parampil)
- Operations Officer, Unit II (Evi-Carita Riikonen)
- Science Officer, Unit II (Janne-Markus Rintala)
- Operations & Networking Officer, Unit II (Syed Ashraful Alam part-time from 1.2. until the contract ended 31.12.2020)
- Communications Assistant, Unit III (Mari Keski-Nisula)
- Senior Officer, Communications (ENVRI-FAIR), Unit III (Magdalena Brus)
- Executive Assistant, DG Unit (Inka Hellä)
- Junior Controller, Unit I (Shawnie Kruskopf)
- EU-project Administration Assistant, Unit I (Leysan Karimova)
- Officer (SEACRIFOG project), UNIT III (Mylène Ndisi contract ended 31.12.2020)
- Communications Assistant, UNIT III (Karlina Ozolina)
- Senior Officer, Data Analyst, Unit II, (Ville Kasurinen)
- Observation Network Officer, Unit II, (Maiju Tiiri)

Contract management

The contract of the Director General was renewed. The Cooperation Agreements with the Central Facilities and the tasks lists for the Agreements have not been updated. Pirjo Kontkanen, a research funding lawyer at the University of Helsinki, continued as the legal advisor to ICOS ERIC and the Audit company was KPMG. The Secretary of the Evaluation Board had been located at the Head Office premises and she was been hired from a staffing firm.

Operational management of ICOS ERIC and RI

An advanced draft of the **Management plan** was completed and provided to GA for comments. The draft was discussed in the November GA and further development needs were identified; to be discussed again in spring 2021.

ICOS ERIC provided support for the Evaluation Board by providing materials and information for the Board. The process was iterative and time consuming, but resulted in material which can be used in improving the operational activities of the RI beyond the level of details discussed in the Evaluation report. The surveys conducted among RI members and stakeholders provided data that is useful in the implementation of the **Engagement plan** that relies on first-hand information from all parts of the RI.

The ICOS Handbook was updated, and the 2020 edition already contains introduction of ICOS Spain and ICOS Poland.

18 stations were labelled, and contracts were prepared between the ICOS ERIC and the host organisations of labelled stations.

Support for ICOS-related science

A cross-domain study group was formed to study the effects of anomalous winter of 2019-2020, lead by Ocean MSA and facilitated by HO.

At the initiative of the OTC, preparations for a Marie Skłodowska-Curie Action (MSCA) Doctoral Network training proposal are underway. If successful, the MSCA will support around 10 PhD positions within ICOS community and joint training events, which will contribute to training the next generation of ICOS scientists. The pan-ICOS proposal aims to train the doctoral students as data users and potential new PIs, capable of effectively bridging the gap between science and policy. The proposal will be submitted in second half of 2021, details are still to be confirmed, as EC prepares for Horizon Europe programme.

(See also Science conference and Drought special issue in Highlights)

Communication and community integration

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.

External communications and outreach

The ICOS Head Office continued to promote ICOS mission and its services to a wide range of stakeholders.

In Finland, ICOS ERIC organised its second Fridays-for-Future climate change event together with ICOS Finland and the Finnish Meteorological Institute. The fully booked event gathered some 200 of 15-20-year-old youngsters. The programme consisted of short scientific speeches and of a meet and greet session with scientists.

In spring, ICOS ERIC and ICOS Finland organised an ICOScapes exhibition at the Natural History of Finland in Helsinki. The museum offered one of its newly renovated halls for the ICOS exhibition, organised guided tours, as well as workshops for children and youth during holiday season. The event gathered approximately hundreds of visitors, however, exact numbers were not possible to count due to layout of the museum exhibitions. In connection with that, huge ICOScapes pictures were presented on the Environmental ministry. We were lucky that all this could be done before the Covid-related lockdown measures were established.

All in all, ICOScapes cooperation with the famous photographer Konsta Punkka continued to gain visibility for ICOS in social media. He has sometimes posted ICOS related posts or comments on his Instagram account, and by association, ICOS has gained tens of thousands of views and dozens of comments.

ICOS materials, website, media and social media

In 2020, ICOS Head Office and Carbon Portal finished their project of jointing their two separate websites to one central hub, at the same time redesigning the whole website, including the visual appearance, structure and many of the functionalities. The result now presents ICOS ERIC as one entity, linking in also Central Facilities in a more unified way.

ICOS' external communication activities include production and dissemination of a wide range of engaging content across a variety of channels. A new and improved, 2020 edition of the ICOS Handbook was published. It is widely used and appreciated by the community members as well as by aspiring ICOS countries. The printed document was sent around the RI.

Further, ICOS ERIC published 48 pieces of news on its website in 2020 (27 in 2019), which reflected the active year of ICOS.

In social media, ICOS focuses its efforts on Twitter, Instagram, YouTube and LinkedIn. During 2020, our presence on Twitter, YouTube and LinkedIn has continued to grow. The number of Twitter followers increased by 41%, and LinkedIn group by 17% compared to 2019. The number of Instagram followers has decreased slightly, by 8%, largely due to the fact that ICOScapes campaign has finished. Videos published on ICOS YouTube channel have gained 203% more views in 2020 compared to 2019. Additionally, ICOS was mentioned at least 234 times in traditional media outlets in 2020, for example, in relation to Spain joining ICOS.

Additionally, due to Covid-related restrictions, several events in which ICOS traditionally participates, such as EGU, AGU and GEOWeek, were turned into online events. Consequently, ICOS also turned its participation in an online format.

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.

Community integration

Community integration refers to the RI's ability to include different parts of the RI into activities, the ability to improve activities and respond in an agile way to new opportunities or challenges, and the potential for improving the RI's structure.

The most important activity supporting community integration was naturally the ICOS Science Conference, which was turned into an online format and was a huge success. More information about the Science Conference, please read the 'Highlights' section, page 8.

ICOS community also organised several trainings and workshops to develop things together. Most of those took place in online format. For more information, please refer to chapter ICOS National Networks 2020, page 42.

Besides activities, communication is an important glue fitting the community together. To that end, the Head Office and Carbon Portal regularly supports internal communication activities across the ICOS RI. To enhance cooperation and timely communication across the RI, the HO continued to publish a monthly community newsletter, while the ICOS Carbon Portal maintained internal document management system as well as enabled a new discussion forum at Discord platform. (Read more on

those in the Carbon Portal section, page XX) The HO also continued the good cooperation with the RI Communications Network in order to align messaging and to share information and best practises.

International Cooperation

The year 2020 hosted two major achievements in the field of international cooperation for ICOS. The first one is the **membership of Spain in ICOS**. ERIC Announced by the Spanish authorities at the end of 2019 during a side-event organized by ICOS at the COP26 in Madrid, the membership was finalized during the year and accepted by the General Assembly of ICOS ERIC in November 2020. Despite the difficulties and delays due to the world health situation, the Spanish authorities persistently passed all the necessary milestones in the legal-administrative process. Spain brings to the ICOS monitoring network two new stations: the Izaña station (Atmosphere Class 2) on the Canary Islands and the CANOA VOS-line from the Canary Islands to Barcelona (Ocean Class 1). The extension of the geographic coverage obtained through the Spanish stations is a welcome improvement for the scientific relevance of the ICOS network.

The second achievement was the signature, after the approval of the General Assembly of ICOS in November 2020, of the **Memorandum of Understanding establishing the Global Ecological Research Infrastructure (GERI)**. The MoU is the successful completion of a long-term cooperation between ICOS and five regional research infrastructures of major importance: The Chinese Ecosystem Research Network (CERN), China, the European Long-Term Ecosystem Research – Research Infrastructure (eLTER RI), Europe, the National Ecological Observatory Network (NEON), USA, the South African Environmental Observation Network (SAEON), South Africa, and the Terrestrial Ecosystem Research Network (TERN), Australia. The overarching goal of this MoU is to provide and advocate a vision for a global Research Infrastructure making terrestrial and coastal in situ observations, building upon strong, integrated and sustainable regional Research Infrastructures. Particular attention will be given to the development of a hierarchical system of essential variables for ecological observations, of coherent international standards, of open and FAIR data practices as well as to the support of the existing global data initiatives (such as RDA, FluxNet...). This MoU is an important step on the way to the recognition of GERI as the first distributed Global Research Infrastructure (GRI) by the Group of Senior Officials (GSO) of the G7.

Green Team

The Green Team of ICOS ERIC reported for the first time in 2020 the 2019 greenhouse gas emissions related to business travels (BT) and home-work-home (HWH) commuting of all personnel of the ERIC (HO + Director of CP). The results were as followed: a total of 106 tons of CO_{2eq} were emitted. This represents a total of approximately 102 tons for BT and 4 tons for HWH commuting. Calculated on the basis of full-time-equivalent (FTE) employees, the results are 6.25 tons/FTE, equal to approximately 6 tons/FTE for BT and 250 kg/FTE for HWH. The Green Team suggested at the beginning of 2020 a reduction target of 10 % of the total emissions for 2020. This was considered an ambitious target, before the Covid pandemic changed the situation. Among other reduction actions, the Green Team suggested each employee should work 1 day/week remotely from home.

Carbon Portal tasks

Highlights

- Drought-2018 special issue
- Virtual Jena meeting (elab products)

- Python library for direct M2M access to ICOS data (elab products)
- CoreTrustSeal application

Data service development

Emphasis of the development of the services has remained to be on stability, user friendliness and performance of the services. In the framework of ENVRIFAIR we specified several medium to small improvements to make the CP repository even more FAIR. The emphasis of these changes was directed at reproducibility and alignment with the other environmental RIs.

The increase in performance of the SparQL queries by optimising the searches through smart (magic) indexing proved to be robust and was able to handle the further sharp increase of number of data objects and number of downloads. Through 2020 all Thematic Centres released Level 2 data products and except Ecosystem domain all released also daily NRT data products for the labelled stations. The increase in the number of labelled stations contributed also to the increase in ingested data objects, together with a sharp increase in ingested elaborated products, for example connected to the Drought2018 initiative.

All CP services have been online in 2020 for more than 99.9% of the time. Short hiccups again appeared only due to interruption of the storage services at the trusted repository.

In 2020 we also started making full use of our third server (fsicos3) that was installed at the end of 2019. This server provides 128 cores and a large amount of fast working memory (512 GB) and spinning disk storage memory (40 TB), ideal for serving the virtual machines running Jupyter notebooks in our Jupyter and ExploreData services and to run the operational STILT footprint modules and the trajectory forecast services. The older server fsicos1, dating from 2014, will now serve a back-up server and to test and stage services before deployment.

Based on user feedback, many improvements, large and small, have been applied to the portal app to improve the user experience, ease of access to the data, previews and the search workflow. An important addition to the search app is the [Main Data Products](#) page on the ICOS website, that summarises all the latest Level 2 and NRT datasets, together with a selection of important historical datasets (Drought-2018 and InGOS) and to showcase important elaborated products with a strong connection to ICOS.

The increased use and download of ICOS data necessitated to redesign the storage of data download information as the original solution using MongoDB was showing performance issues with queries taking several seconds and sometimes causing timeouts and incorrect results in the user interface. In order to be ready for further growth we switched to storing less information and using Postgress as the database, which reduced the query time to several milliseconds. This change also required to revamp and streamline the user interface for data download statistics at <https://data.icos-cp.eu/stats/>.

The exchange of station metadata through the improved mechanisms developed in the framework of the Data Lifecycle Working Group and RINGO became operational and resulted in improved data citations and station landing pages for all labelled stations. Each Thematic Center developed together with the respective MSAs a scheme for roles at the stations and which roles are reflected in the citations and how these influence the citation order. The metadata flow will be further enhanced by including instrument and provenance metadata.

Data and data usage statistics

The number of downloads from Carbon Portal increased further to 554 108 in 2020 (2019: 430 915). The number of downloads of ICOS final quality data (Level 2) and Near Real Time data objects in 2020 was

145 245. In 2019 this was an anomalous 251 156 due to one server in Germany downloading automatically all NRT data at a daily basis. The number of Level 2 data downloads in 2020 was 65 136 (2019: 38 590); of these the largest portion of 46 466 downloads is Atmosphere data (2019: 25 843). As one can see in the right plot of Figure 1 the combined downloads of L1+L2 show a clear upward trend over the year 2020.

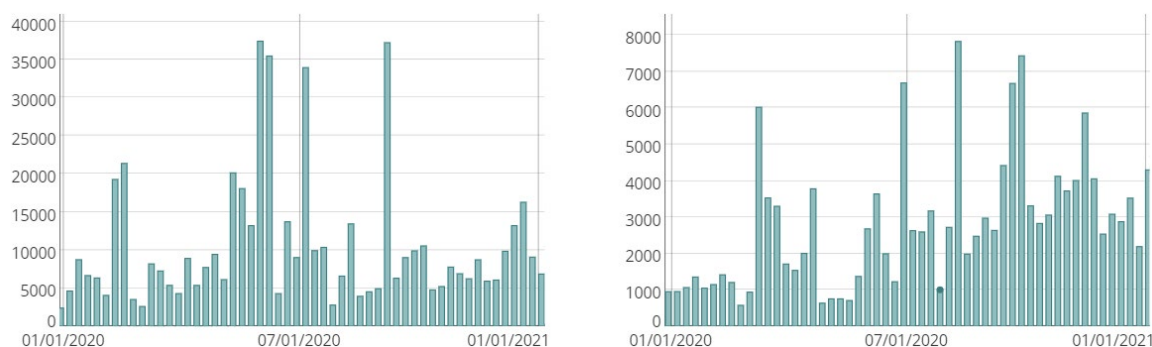


Figure 1. Number of downloads per week of all (left) and L2+NRT (right) data objects at ICOS Carbon Portal during 2020. Peaks in download occur right after important events like for example the Drought-2018 and L2 releases.

Table 1. General overview of website statistics and downloads for the whole year of 2020

Total nr of unique visitors	62 584		
Pageviews	234 622		
Average session duration	2m:16s		
New sessions	64.47%		
Data objects stored			
All end 2019->end 2020	217 625	- >	428 976 (incl. deprecated objects)
All end 2019->end 2020	142 076	- >	262 064
L1 end 2019->end 2020	607	- >	1 239
L2 end 2019->end 2020	5 477	- >	5 836
L3 end 2019->end 2020	31	- >	225
Data downloads			
All data	554 108		
ICOS Level 1	80 289		
ICOS Level 2	65 136		
Level 3	55 661		
Data previews			
Timeseries	8 256 (CO ₂ : 4 202; CH ₄ : 1 126; NEE: 915)		
Spatial	93 (MACC inversion result: 43)		
Ship tracks	238 (Polarstern: 46)		

ICOS Carbon Portal minted 182 DOIs in 2020 (2019: 77), mainly for L2 data products and collections of L2 products. In total now ICOS has minted 302 DOIs, next to the 428 000 Handle PIDs.

The geographic spread of downloaders of ICOS data is shown in figure 2. The largest number of users from the USA is mainly attributable to downloads of the Global Carbon Project data and the downloads of ICOS atmospheric L2 data in the NOAA Obstack products, that also are registered and counted at Carbon Portal. Similar mechanisms for download usage tracking and citation tracking through ICOS minted DOIs attached to the data are foreseen and agreed upon for ICOS data linked to FLUXNET and SOCAT data products.

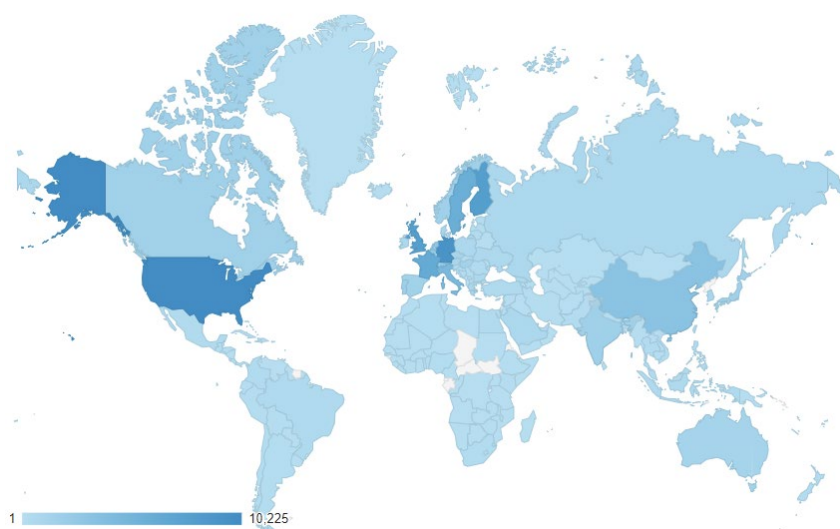


Figure 2. Geographic spread of the ICOS web site users for the year 2020. Biggest number of users is from the USA (10 225), followed by Germany (9 228) and Finland (7 907).

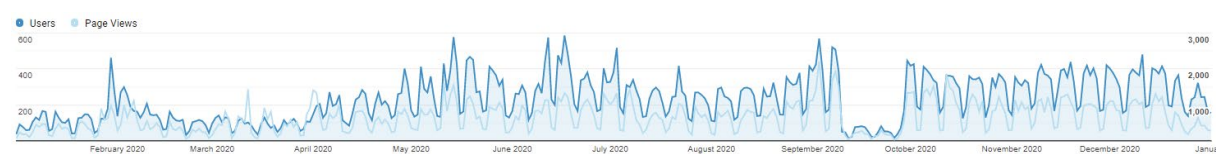


Figure 3. Number of unique users (left axis) and page views (right axis) per week on the ICOS web pages and services

Infrastructure support

The Nextcloud fileshare and the integrated document editor OnlyOffice has further gained use by the ICOS community with over 400 active users. The Document Management System Alfresco was terminated in December 2020 and all documents have been transferred to the Nextcloud system.

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 increasingly time-consuming task.

Data management and elaborated products

In June 2020 ICOS Atmosphere released a pre-release of the Level 2 data just for CO₂, to accommodate the request from WMO for an early release of the data. On 7 September 2020 the full Level 2 2020-1 release of ICOS Atmosphere was released by the Atmosphere Thematic Centre through Carbon Portal for 25 labelled stations and in total 62 vertical levels.

ICOS RI. (2020). ICOS Atmosphere Release 2020-1 of Level 2 Greenhouse Gas Mole Fractions of CO₂, CH₄, CO, meteorology and ¹⁴CO₂ (1.0). ICOS ERIC - Carbon Portal. <https://doi.org/10.18160/H522-A9S0>

On 14 July 2020 the second Level 2 release for ICOS Ecosystem for 16 stations was released:

ICOS RI. (2020). Ecosystem final quality (L2) product in ETC-Archive format - release 2020-1 (1.0). ICOS ERIC - Carbon Portal. <https://doi.org/10.18160/ABWE-HMV4>

On June 2020 the Ocean domain published its first L2 product for 5 stations:

ICOS RI. (2020). ICOS Ocean Level 2 Data Release 2020-1 (1.0). ICOS Carbon Portal.
<https://doi.org/10.18160/JJ9T-8577>

On 10 March ICOS also released the final public release of the observational data from the Drought 2018 task force for ecosystem. This data set includes eddy flux data from all 52 stations that participated in this initiative.

Drought 2018 Team, & ICOS Ecosystem Thematic Centre. (2020). Drought-2018 ecosystem eddy covariance flux product for 52 stations in FLUXNET-Archive format (Version 2.0). ICOS Carbon Portal.
<https://doi.org/10.18160/YVR0-4898>

On 4 March 2020 the time series data from 48 atmospheric (ICOS and non-ICOS) stations was released:

Drought 2018 Team, & ICOS Atmosphere Thematic Centre. (2020). Drought-2018 atmospheric CO₂ Mole Fraction product for 48 stations (96 sample heights) (Version 1.0). ICOS Carbon Portal.
<https://doi.org/10.18160/ERE9-9D85>

Both Drought-2018 observational time series go back for some stations to 1979 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.

The support of regional CO₂ inversions was continued also in 2020. Updated results of the EUROCOM inversion intercomparison and the inversions analysing the drought 2018 were published with DOIs at CP as supporting material for two scientific papers as well as for further dissemination in European carbon budget studies.

The Jupyter Notebook services at CP were further upgraded during 2020. The collaborative Jupyter Hub, currently hosting 80 users, now offers advanced options like sharing notebooks and data between users. It allows users to upload own data for analysis together with ICOS data, and provides permanent storage of notebooks and data. This service is continuously expanded in close consultation with our users to support their scientific analysis and interpretation of ICOS data and products.

Easy access to the Jupyter notebooks for exploring and analysing ICOS data for scientific and educational purposes is provided through the public exploredata.icos-cp.eu service, which does not require registration, offers full functionality of the notebooks, direct read-access to ICOS data but no storage beyond the active session. This service currently allows 60 users to be active at the same time.

An ICOS-specific python library to support easy access to ICOS data in a python programming environment is now available in the CP Jupyter Notebook services and for installation on local computers.

The STILT footprint tool and the tool for computing daily updated forecasts of backtrajectories are frequently used by scientists related to ICOS. Footprint tool results and their further analysis in Jupyter notebooks have provided support for several scientific publications and presentations.

On 1-2 April 2020 CP held a virtual workshop to identify products and services that could potentially be of interest for the ICOS community but also for the wider scientific community. During the 2-day workshop 50 participants from the atmosphere, ecosystem and ocean ICOS community, the TCs, HO, and CP discussed ideas and strategies to extend the portfolio of elaborated products and services hosted at CP. Specific discussions were centred around scientific and technical aspects of the FLUXCOM ecosystem flux product, the FluxEngine ocean flux tool, the atmospheric inversions demonstrator, and the needs for upgrading already existing tools and products. Based on the outcome of the discussions CP is continuing the development of tools for analysis, visualisation and dissemination of products, mostly via the Jupyter Notebook services.

CoreTrustSeal application

Through the FAIRsFAIR project ICOS 'won' support from this EU project to develop the application for the CoreTrustSeal certification of our data repository. The support consists of financial support of € 10 000 to cover the cost of the application and part of the personnel effort and support by the FAIRsFAIR project team through webinars and test reviews of the applications. CP submitted a test application in October for review that was evaluated and based on the feedback the application will now be improved and is expected to be ready for submission mid 2021.

Training and user support

In cooperation with ICOS-Sweden a PhD course on carbon-balance mapping was given in Spring 2020. The course was organized as part of the ClimbEco Graduate Research School at Lund University. This research school is open for students at the Swedish Universities. The course focused on different methodologies used in scaling carbon monitoring measurements and application of inverse methods based on observations, atmospheric transport and dynamic vegetation modelling. Besides lectures on the different methodologies, also different tools developed at the ICOS-CP and examples of Jupyter notebooks were introduced to the 13 PhD students as part of the exercises. The course was evaluated as excellent by the students, by one even as the best course ever taken at Lund University.

As mentioned before in the 2019 report Carbon Portal support was instrumental in making the Drought 2018 task force a successful community effort. In 2020 CP curated more data, minted DOIs and collected and organized together with the Thematic Centers the relevant metadata. CPD and Wouter Peters, as part of the editorial team for the special issue contributed to the review process and contributed/wrote the introductory overview paper.

The 5th ICOS/RINGO Summer School "Challenges in measurements of greenhouse gases and their interpretation", was planned to be held in Hyytiälä from 9-15 May 2020, but had to be postponed to summer 2021 due to the restrictions imposed by the COVID epidemic. Recently it has been decided to postpone the Summer School further to mid December 2021, thus transferring this into a Winter School, where the original 35 admitted students will receive a guaranteed place for those still interested.

Training events during which the Exploredata public Jupyter service was used:

- 26 August 2020 - INES seminar at Lund University "ICOS Data at your Fingertips" (presenter: Claudio d' Onofrio)
- 3 September 2020 - INES seminar at Lund University "ICOS Station Characterization" (presenter: Ida Storm)
- 15-17 September 2020 - ICOS Science Conference
- 22 September 2020 - webinar in the series "Towards ENVRI Community International Winter School on Data FAIRness"
- 2-4 November 2020 - OTC online training event "Data Reduction Workshop"

The ICOS-related educational material produced last year as part of a project collaboration between ICOS CP, Swedish Science Centers (SSC) and Lund university dept. of Physical Geography & Ecosystem Science and dept. of Data Science, was developed further in order to be accessible online by everyone. This development was deemed necessary due to the circumstances imposed by the pandemic. This way, all science centers and schools had direct access to the educational material. The project continued in 2020 and led to a new collaboration between Swedish Science Centers and ICOS Sweden, who got funding to produce educational material showcasing i.a. how an ICOS station operates.

Events during which, the new version of the educational material was used:

- January - March 2020 - School visits to a Swedish Science Center (before covid-19 restrictions)

- 11-15 May 2020 - *Klimatfestivalen*; digital event organized by Bolin Center for Climate Research <https://bolin.su.se/klimatfestival-2020/digitalt-aktivitetstorg/svenska-science-centers-1.497196>
- 25 August 2020 - Virtual workshop for all Swedish Science Center pedagogues (training event)
- 1 October 2020 - *Digital idag*; digital event organized by Swedish government institutions https://digitalidag.org/event_2020/digital-klimatprogrammering/
- 6 October 2020 - Virtual training event for teachers "Energy & Climate"
- 8 December 2020 - Virtual training session with high school teachers

Outreach

Below are some indicative numbers regarding the outreach of the developed CP material in 2020:

- Students (age group 15-18): 725
- Teachers (attending workshops/teaching events): 69
- SSC pedagogs: 55
- University students (employed part-time by a SSC): 20

Management

The Carbon Portal involved in 2020 a team of 19 persons, delivering a total of 13 fte, including the external projects (4.3 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.

Throughout most of the year, the management of CP was heavily influenced and complicated by the limitations imposed by the COVID epidemic, which led to all personnel working mainly from home, starting mid-March until the end of the year, and all group meetings took place through online platforms. Internal communication was also assisted by amplifying the use of Slack to the whole team, where before this was only used between the members of the development team. From mid-March on, all travel and external physical meetings were cancelled and replaced by online meetings.

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 monthly ICOS Head of Units video conferences. The CP Director and his substitute are also part of ICOS RICOM, that meets during monthly video conferences and two face-to-face meetings every year.

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 2020 consisted of six H2020 projects (SEACRIFOG, RINGO, VERIFY, EOSC-Hub, ENVRIFAIR, traceRadon), one Swedish national project (SITES) and one international project (COINS-EEA COPERNICUS). The new COINS project and the traceRadon EU project started in September 2020. Of course all plenary project meetings related to the CP portfolio projects have been attended by representatives of CP. The RINGO project ended December 2020 and SEACRIFOG ended in August 2020.

During 2020 CP participated in several new project proposals, of which most were successful, and this will extend in 2021 our project portfolio with the projects ATMO-ACCESS, EOSC Future, DICE and Arctic Passion.

Contribution to several iterations of collecting the evidence report for Evaluation adding a large amount of workload.

International collaboration/initiatives

Extensive development work for CP 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 expert group of the H2020 CHE project (ended in 2020) and member of the advisory board of the MSCA MEMO2 project. This year the now 16th WMO GAW Greenhouse Gas Bulletin was composed by the WMO SAG on Greenhouse Gases and coordinated by CP, with this year as highlight the COVID-19 response due to reduced CO₂ emissions in the atmosphere, with a good coverage for the ICOS activities in this respect. 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 COINS in situ project lead by EEA. In this new contract starting September 2020 we lead a work package to advertise the CO₂ Monitoring and Verification System with the stakeholders, mainly city and regional representatives, and perform a survey to inquire the expectations, possible commitment and interest for such a system in Europe.

AV and MH were active as representatives of ENVRI RIs in the EOSC working groups on Architecture, AAI and PID, with the presentation of white papers on the issues and the initiation of the EOSC Association these working groups were terminated at the end of 2020.

Personnel changes

The position of Scientific programmer Zhendong Wu was extended from part time (25%) to full time to further develop the atmospheric footprint and LPJ-Guess DGVM services. Developer Mitch Selander, who had been active for 50% from the onset of the Carbon Portal, was assigned additional teaching tasks and stopped working for CP per April 1st.

Projects

E-SHAPE

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. 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. In 2020, the project had its first Sprint, which in case of GCGE consisted of further fact-finding of available facilities (such as different DIAS services) and in expected applications withing the project timeframe.

ENVRI-FAIR

WP5 - Common requirements and testbed for (meta)data services, community standards and cataloguing

ICOS CP has a leading role in WP5 of the ENVRI-FAIR project. Since the beginning of the ENVRI-FAIR (January 2019) WP5 has already achieved a series of tasks, several of them included in the 1st periodic report of the ENVRI-FAIR (submitted to the project office in June 2020, M18 of the project). The work has been organised by means of monthly virtual meetings with WP5 participants representing WP(5-11). Following the FAIRness gap analysis and the first round of the FAIRness evaluation (task T5.1, completed in 2019), the CP contributed to the first WP5 deliverable (D5.1, co-authored) submitted in February 2020. Since the ENVRI week in February 2020 (f2f meeting in Dresden), six (6) cross-domain thematic groups were formed (Task Forces, hereafter TFs), corresponding to commonly identified targets which will help the cluster to improve their FAIRness (part of task T5.2 led by ICOS). ICOS, having the leading role of WP5, has the responsibility for managing the TFs, following the progress of all groups and reporting back to the community. The CP participates in most of the TF virtual meetings (with ICOS representation, contribution to landscaping exercises, active role in decision making at cluster level, contribution to the ENVRI catalogue, design of the ENVRI-hub and ENVRI use cases); also leading the work on the Persistent Identifiers (TF3 - PIDs, led by Maggie Hellström). Angeliki Adamaki and Alex Vermeulen were the main authors of the milestone report MS17 - Draft Implementation plan (internal report, submitted in March 2020) and the deliverable D5.2 - Implementation plan for common development goals (public document, submitted in September 2020). The CP is also leading the task T5.3 (to be completed in December 2021) with the main goal of developing the ENVRI community Service Catalogue, an important (future) component of the ENVRI-hub. In November 2020, the CP organised a virtual 2-day meeting where the WP5 TF recommendations were presented and discussed with ENVRI representatives.

WP6 - Training and capacity building

WP6 is tasked with providing training that will support ENVRI-FAIR project partners, as well as the larger ENVRI Community, in their work to implement FAIR best practices in their data management. ICOS CP leads work package 6, and is in this role responsible for overseeing and coordinating its activities including the creation of training materials, the organisation of training events, and the dissemination of information about such events to the ENVRI Community and beyond. ICOS CP also chairs regular meetings of the WP core group (key persons from ICOS CP and LifeWatch ERIC).

WP6 aims to provide training on a wide range of FAIR-related themes, identified during a knowledge gap analysis performed at the start of the project; this identified 6 topics related to general research data management (RDM) and the FAIR principles, and 22 topics related to core RDM concepts and how to implement these by applying technological solutions and recognized standards. ICOS CP experts have participated in a number of ENVRI-FAIR training sessions, both in a moderator role and as instructors. The latter included a well-attended webinar on how to use Virtual Research Environments (VREs) based on Jupyter Notebooks, presented by Karolina Pantazatou, Claudio D'Onofrio, Ute Karstens and Ida Storm. In addition, Maggie Hellström and Maria Johnsson are actively engaged in a number of RDM training-related working and interest groups under the Research Data Alliance, and have participated (on the behalf of ENVRI-FAIR WP6 and ICOS CP) in several workshops on best practices for teaching FAIR principles, and how to make training materials and events FAIR.

The CP also participates in the subdomain WPs (WP8-Atmosphere, WP9-Marine, WP11-Ecosystem) supporting the ENVRI-FAIR activities (implementation plans, improving FAIRness) of the corresponding thematic centres.

EOSC ENHANCE

CPD represents the ENVRI-FAIR project to follow the further development and specification of the EOSC Portal together with representation of the other ESFRI science cluster projects. This project is an intermediate and short-term project to fill the gap to the start of the EOSC Future project that is

supposed to begin mid 2021 and that will further operationalise the EOSC system. Important developments, specifications and requirements, for example on the on-boarding process for services in to the EOSC Portal and the development of metadata standards for describing services and data are fed back into ENVRIFAIR through its WP5.

EOSC-Hub

In this project ICOS developed a demonstration service for the processing of eddy covariance flux data in the EOSC cloud for external parties. The work on this project ended by the end of 2020 and unfortunately could not deliver the end product due to the fact that the data processing pipeline from ETC, that was meant to be part of the system, was not ready for deployment.

ERIC FORUM

In the ERIC Forum project, ICOS ERIC participated in discussions about the ways to measure and convey the socio-economic impact of ERICs, provides the project website and email lists, and continued to plan an online toolbox to stay current about ERIC-related issues and to facilitate the process of becoming an ERIC.

PAUL (still a proposal)

A consortium coordinated by ICOS ERIC, consisting of 30 partners, prepared a proposal to the EC Green Deal call of Urban observatories. Many of the beneficiaries are members of the ICOS community. Pilot cities, Munchen, Zurich and Paris, were selected with help of an independent board.

RINGO

Ringo was completed, see highlights.

SEACRIFOG

The project ended in 2020. After a long review process the SEACRIFOG paper on network design for an atmospheric GHG observations system for Africa based on Flexpart simulations by CP and an inversion model from Bristol University was accepted and published. The conclusion is that with a network of 6-10 well placed new stations, but located at existing infrastructures of different observation networks, the GHG budget of Africa can be constrained with considerable reduction of uncertainty. Hopefully follow-up projects will allow to further establish such a network by building on the results of this project.

SITES

ICOS CP continued hosting and developing the SITES data services. Metadata was defined for the main thematic programs (Station base data, SITES Water, SITES Spectral, and SITES AquaNet) which enabled stations to upload the first quality checked data. More than 300 of these data files were uploaded by the end of 2020.

traceRadon

ICOS CP contributes to the (EMPIR) 19ENV01 project traceRadon with the development and evaluation of a radon flux map as service for atmospheric transport model evaluation as well as for radiation protection applications (WP3 led by Ute Karstens). The main goal of the project is to establish

metrological traceability for low-level outdoor radon activity concentrations measurements (a recommended measurement parameter at ICOS atmosphere stations) and radon flux measurements.

VERIFY

The aim of the H2020 VERIFY project is to develop a pre-operational system to estimate greenhouse gas (GHG) budgets and support countries in their reporting tasks to the UN Framework Convention on Climate Change. The main role of ICOS in the project is to contribute to the communication of the project and the dissemination of its results. Due to the COVID pandemic, many events were postponed and the project has applied for extension.

ICOS has an important role in the in situ component of the new architecture envisaged by the European Commission for a Monitoring and Verification Support (MVS) Capacity. This endeavour will be built on the results of VERIFY and the other related H2020 project CHE, and it is further developed in the follow-up project CoCO₂, starting in 2021.

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 Lampedusa Italian station has started to transfer GHG data and meteorological data.
- The Plateau Rosa Italian station has started to transfer GHG data and meteorological data.
- The Station Nord Danish station has been registered and has started to transfer GHG data and meteorological data.
- The German Helgoland station has been registered and has started to transfer GHG data and meteorological data.
- The German Zugspitze station has been registered and configuration was ongoing at the end of 2020

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. News sections have been added
 - File processing status summary; a table which gives an overview of the different information detailed in the rest of the report. If everything is OK, no need to read further otherwise the PI should read on!

- A list of the undeclared valve positions in the Picarro data files. This is can be an important feedback for the Pis who are not carefully checking their daily automatic emails.
- Calibration computing issues. This section reports instrument calibration issues by species. The problematic tanks are listed.

File processing status summary

File size	Valve position	Data flagging	Calibration computing
OK	KO	OK	OK

Undeclared valve positions

Date	Undeclared valve positions *	Period
2020-05-03	69.08% (7875)	[2020-05-03 22:06:21.0 ~ 2020-05-04 00:06:32.0]
2020-05-04	69.08% (7875)	[2020-05-04 00:06:33.0 ~ 2020-05-04 03:06:48.0]

* Only files with more than 5% of undeclared valve positions are taken into account. If there are more than one file in a zip archive, the threshold is applied to each individual file.

Calibration computing issue

CO2

Date	Description	Tank identifier(s)
2020-09-13	The calibration starting the 2020-09-13 06:09:00.0 has 2 invalid tank(s) because the number of valid cycles by tank is below the required minimum (2).	D477541 (got 1 cycle(s)), D477531 (got 0 cycle(s)),

CH4

Date	Description	Tank identifier(s)
2020-09-13	The calibration starting the 2020-09-13 06:09:00.0 has 2 invalid tank(s) because the number of valid cycles by tank is below the required minimum (2).	D477541 (got 1 cycle(s)), D477531 (got 0 cycle(s)),

CO

Date	Description	Tank identifier(s)
2020-09-13	The calibration starting the 2020-09-13 06:09:00.0 has 1 invalid tank(s) because the number of valid cycles by tank is below the required minimum (2).	D477531 (got 1 cycle(s)),

- Improve traceability of automatic processing warning and errors by adding more information in the database. These information being structured they will more easily be used to analyze the data and generate reports. Start to use event tables to trace semi manually the problems which happened at the ATC like transfer problem to the Carbon Portal.
- Finalization of the processing chain taking car of the 14C from the CRL.
- Development of the program taking care of the interactions flask sampler-ATC. It is a new type of interaction where the ATC not only receives data but has to send back answers asynchronously. This first version uses a simple computed CO background and a set of parameters. The parameters, the requests and answers are traced in the database.
- Update of the metadata processing chain which can now ingest campaign metadata including mobile campaign like AirCore campaign.
- Add monthly means output computed on the fly for Picarro, Los Gatos, meteorological and radon data. Add radon daily means output computed on the fly.
- Speed improvement of the insertion of meteorological data and analyzer data. Memory leak and dead lock tracking.
- L2 data are now stored in the database at the same time they are released and sent to the Carbon Portal. The associated hourly means computed without the detected spikes are stored along with the L2 GHG data.

NRT data production (Task 1.2)

A total of 31 stations are connected to ATC, sending their data to ATC and, consequently, are able to be processed in NRT mode. This represents 12738 (+11% compared to 2019) raw archive files (~104Go, +28% compared to 2019, for a mean of 7.6Mo/station/day) processed for an availability rate of ~0.98 (+0.01 compared to 2019) for 29 (+6 stations compared to 2019) stations which transmit their data over the complete 2020 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).

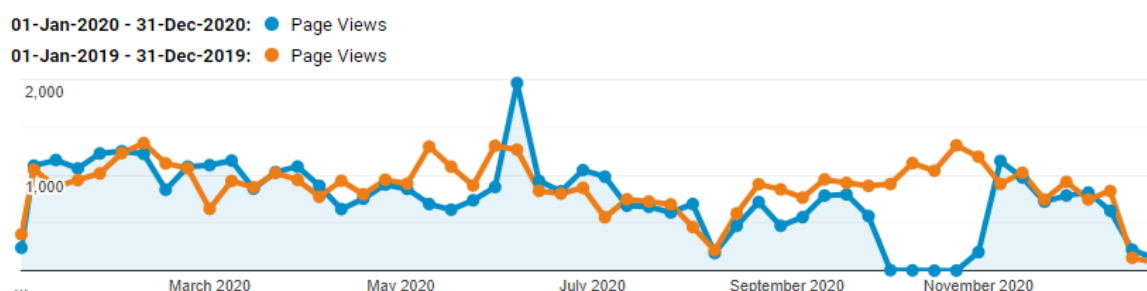
In 2020, 68 families of graphical NRT Data Products, (~ 5888 products in total, which represent an decrease of -29%/2019, for ICOS network stations) are produced daily from NRT measurements (total volume of 1.04Go (-0.44Go/2019) and freely available on the ATC website for station monitoring and diagnosis. The decrease in volume and number of products is due to a rationalisation of the data production chain, where outputs of some families of graphical NRT Data Products were too verbose.

Those Data Products are helpful for PIs to verify the status of their stations. In total, for the year 2019, nearly ~3314 (+200/2019) users have interacted with ATC's website, for ~40054 (-1%/2019) page views. Note that the audience measurement was not available during one month (October, 4th – November 4th), when the ATC website migrated from drupal 7 to drupal 8, which explains the drop in audience, compared to 2019.

Figure: Page views for 2020 (in blue), compared to 2019. Spike in June 2020 is for Atmosphere MSA.

Level 2 data production (Task 1.4)

The new Level 2 (2020-1 release final quality controlled observational) data from the atmospheric network has been released on September 2020 by the ICOS Atmosphere Thematic Centre. This 2020-1 release containing data from the atmospheric network of ICOS Research Infrastructure for 26 stations and 62 vertical levels at Gartow, Hohenpeißenberg, Hyltemossa, Ispra, Jungfraujoch, Karlsruhe (KIT), Křešín u Pacova, La Réunion, Lampedusa, Lindenberg, Lutjewad, Monte Cimone, Norunda, OPE, Ochsenkopf, Pallas, Puy de Dome, Saclay, SMEAR-II Hyytiälä, Steinkimmen, Svartberget, Torfhaus, Trainou, Utö - Baltic Sea and Zeppelin Observatory. This collection contains the final quality controlled hourly averaged data for the mole fractions of CO₂, CH₄, CO and meteorological observations measured at the relevant vertical levels of the measurements stations, and where available ¹⁴C in CO₂ in two-weekly integrated samples, for the period September 2015-June 2020. All stations follow the ICOS Atmospheric Station specification V2.0 ([doi:10.18160/GK28-2188](https://doi.org/10.18160/GK28-2188)) 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](https://doi.org/10.5194/amt-9-4719-2016)).



Network coordination, training and development (Task 2)

Instrument testing (Task 2.1)

The COVID-19 in 2020 has impacted the ATC Metrology Lab (MLab) workplan due to restrictions related to lockdown and curfew in France. However ATC 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. The COVID-19 has mainly impacted the technology watch activities due to restrictions at LSCE but also in other research labs and manufacturers.

ATC MLab has performed several tests on stainless steel tubing as few ICOS station sampling system tests performed in the field (SAC, TRN) have shown significant bias on CO₂ related to this type of tubing. The related requirement is to avoid the use of stainless steel tubing when the humidity of the air sample change (e.g. tubing downstream the Valco while the ambient is not dried with a cryogenic water trap).

ATC has published (with a DOI) a new release of the ICOS Atmosphere Station Specifications including this requirement amongs other major update (Nafion setup...).

ATC improved the procedure for in-situ testing 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 published on its website and presented during the MSA the test report of 2 different analyzers from LICOR using OF-CEAS technology as a possible candidate for CO₂ and CH₄ measurement: LI-7810 (CH₄/CO₂/H₂O) and LI-7815 (CO₂/H₂O).

ATC is still working on performance testing and characterization of several mid and low-mid cost sensors for CO₂ and CH₄ 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...). This testing is the first step preparing the new H2020 proposal PAUL submitted by ICOS and focusing on CO₂ emission in 3 urban areas: Paris, Munich and Zurich.

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).

Manpower for running the Mobile Laboratory is planned to be two full-time persons. A new person started to work for Mobile Laboratory in March 2020, after the other position became vacant in 2019. The Mobile Laboratory has a fully equipped van, which can be used for parallel measurements. The instrumentation of the Mobile Laboratory includes at the moment a Picarro G2401 (CO₂, CH₄, CO), a Picarro G5310 (CO & N₂O) and an Ecotech FTIR (CO₂, CH₄, CO, N₂O). In 2019, the Mobile Laboratory

instrumentation was complemented with a freeze-dryer unit manufactured by ICOS Central Analytical Laboratory (CAL), and in 2020 the Mobile Laboratory started to measure as dry during the audits.

French atmosphere station Saclay (SAC) was audited in 2019 and the audit report finalised 2020. In spring 2020, German station Lindenberg (LIN) was audited and the report is under preparation. In addition to normal audit activities, a process to improve the precision of the detector of FTIR instrument was started.

As a part of QC procedures of the Mobile Laboratory, it monitors calibration scales between ICOS CAL and Mobile Laboratory, using travelling cylinders prepared by WMO/GAW Central Calibration Laboratory.

Training activities for ICOS atmospheric measurements (Task 2.3)

Due to the Covid-19 context, ATC has organized the first “online” training which required a reorganization and the implementation of suitable tools (virtual class room...). The attendees of this training were Pis/Staff from Germany, Finland, UK and Switzerland. It late over 3 days.

All the initial training requested for new ICOS comers and step 2 labelling have been provided by ATC.

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. These standard training might be online and face-to-face meeting at LSCE (more suitable for experimental practical work). In addition, ATC is working on Webinar 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. The first webinar in 2021 should focus on data quality control and new features on ATC QC tools.

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 2020 as well as the two RICOM face to face meetings. Station labelling process, Steps 1 and 2 (Task 2.5)

Labelling of 3 new ICOS Atmosphere stations in 2020: HEL, SAC and LMP

A ICOS Atmosphere labelling paper has been submitted and accepted in 2020 by C. Yver-Kwok from ATC and published early January 2021.

Ecosystem Thematic Centre (ETC)

Highlights

- Level2 data production (partially influenced by COVID situation)
- 13 stations labelled
- Warm Winter synthesis activity data production

Data collection and availability (Task 1)

The data collection continued as in the previous years with an increase of the stations submitting data to the ETC and to the Carbon Portal. All the labelled stations and the stations under labelling procedure submitted also the metadata and the additional data needed for the processing. Vegetation samples and soil samples, although reduced due to the COVID19 pandemic that limited the possibilities to work at the stations, have been collected by respectively 27 and 4 stations and submitted to the ETC labs in France for the analysis.

Level2 data have been produced and distributed through the CP and the code for the NRT for the quality control run daily with communication to the Pls for prompt interventions. The NRT product for user has been tested and shared with the MSA for comments and improvements, the code run in the Carbon Portal correctly. All the codes are on GitHub.

Raw data transfer (Task 1.1)

Continuous data (eddy covariance and meteorology): the 20 Class1 and Class2 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 station, additional 6 are submitting continuous raw data daily (in the Step2 process of the labelling).

Ancillary data and metadata: all the labelled stations, including the Associated stations, submitted the requested large number of metadata describing the sensors and setup, the changes and the other biological information. All the data are archived in the ETC database and are 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 2020 different forest sites used the FieldMap instrument provided by the ETC.

Digital Hemispherical Pictures and ceptometer files: DHP and ceptometer files have been submitted by stations in Step2. For both data types the routine and tool to upload them automatically in the CP system including all the needed metadata and to retrieve the PID is active and running.

Vegetation samples: 27 ecosystem stations collected and submitted a total of 989 samples to the ETC labs (in 2017 there were 10 stations and 318 samples, in 2018 21 station and 671 samples, in 2019 26 station and 934 samples). The trend is still increasing although the complications due to the COVID19 pandemic and consequent lockdown in different countries. All these samples are labelled and archived, for 84% of the samples the analysis results are already available and loaded in the database.

Soil samples: in 2020 we received soil samples from three sites out of four that did the sampling for a total of 411 samples, of which only 99 samples were analysed, due to COVID19 delays. The analysis have been completed for the samples collected in 2019 and results imported in the database and ongoing and under finalization for the others.

NRT data production (Task 1.2)

The NRT data automatic check of all the raw data is operational and running 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 between 6 and 7 AM CET and send an automatic message to the station team with the results.

The NRT fluxes calculation has been also implemented in the Carbon Portal machines. The example of NRT data product has been shared with the MSA, including examples of diagnostic plots for feedbacks. The MSA discussed them at the last meeting and final consolidated list of suggestions is expected soon.

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 for 16 stations labelled until the spring GA of 2019 as completed in June 2020 and the product released. The COVID19 lockdown created delays in the data processing mainly due to difficulties in the connection by the ETC staff to the clusters used for the elaborations.

Eddy covariance and meteo: the processing has been applied to the raw data and the QAQC scheme developed by the ETC and published in Vitale et al. 2020 applied. The Level2 data include also a standard product used in the FLUXNET community and for this reason fully compatible with the other international networks. The code used for the processing and quality control is also published in GitHub in the ICOS ETC repository. All the relevant metadata are also distributed using a standard format in use in the FLUXNET community and described in Pastorello et al. 2020.

Ancillary data: for the same labelled sites all the ancillary data, including for example LAI, Species, Biomass, Litter, Trees characteristics etc. have been processed and distributed using the same standard format for metadata. For the LAI in particular the DHP and Ceptometer raw data have been quality checked and processed and the results aggregated for the Level2 product.

Critical aspects have been identified and corrected in order to improve the next Level2 production and release, expected for March 2021.

Network coordination, training and development (Task 2)

This task is still important in terms of resources needed because the labelling is in the critical phase and the Instructions and templates are under continuous review and development.

Ongoing development of an coupled IRGA-open-path-anemometer

In 2020 the ETC also continued the development and test of the new prototype of integrated instrument to be used in the eddy covariance measurements in collaboration with CNRS-Reims. The system was successfully tested against a Licor7500 for determining the latent heat flux. An R3 Gill anemometer was bought for building a fully integrated prototype.

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

Seven Ecosystem Instruction documents have been revised and updated in 2020 and one new Instruction on Associates station data finalized and published.

Twelve template for the metadata (BADM) have been revised and improved, in particular in the explanations and rules but in some cases with the addition of new variables. All the modifications are made ensuring back-compliance with the previous versions of the templates. The Frequently Asked Question document shared online has been improved and completed with new topics and specific cases. A completely new BADM has been designed, published and is being used by the Associated stations to provide more information about their setup and instruments.

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. ETC members participated to the

MSA meeting and offered training on request. As it can be imagined the training activities were also affected by the COVID19 situation.

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

The activity and financial plan for the 2021 and the report of the 2019 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, to the meeting the Advisory Board and to the Evaluation process meetings. ETC participated to the RICom meetings and teleconferences.

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

The activities on the labelling continued in 2020 with stations that entered the process and stations proposed for labelling. In particular:

- Six Associated stations started the labelling process and have been positively evaluated. Five of these stations are now preparing the data in order to complete the labelling, one of them (FR-Mej) already submitted the data and was able to get labelled in 2020 (65 days from Step1 start to labelling).
- One Class2 station completed the Step1 of the labelling (NL-Loo, starting the Step2 next month) and two Class2 stations (FR-Lus and NO-Hur) started the Step2.
- A total of 13 stations completed the labelling process in 2020 and have been approved by the GAs. In particular five Class1 (BE-Bra, DE-Geb, DE-Tha, DK-Vng and FR-Lam), two Class2 (BE-Maa and BE-Vie) and six Associated (BE-Lcr, DE-Hai, FI-Kvr, FR-Aur, FR-Mej and IT-Lsn). Also in 2020 6 out of 7 Class1 and Class2 stations have been approved at the fall GA, confirming the general need of the growing season to complete the process for Class1 and 2 stations. In the Associated stations the majority is instead labelled in the spring GA.
- There are 20 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

In 2020 the ETC worked also for the preparation of the ecosystem data for the 2020 European Warm Winter synthesis analysis. Long time series with data up to June 2020 have been collected, quality controlled and processed with the standard ICOS and FLUXNET tools for 57 stations in Europe (including non-ICOS stations) and the results currently under analysis and publication in the ICOS Carbon Portal.

This activity followed the Drought Synthesis data collection in 2019 and it highlights again the importance of the ETC in the coordination of data collections at European scale, that have an impact on the visibility of ICOS and in the involvement of the ICOS scientific community in continental scale studies.

Ocean Thematic Centre (OTC)

Highlights

The Ocean Thematic Centre exists to support the MSA in its core task of delivering climate quality carbon data to the international community in a timely manner so that appropriate policy responses to climate change can be developed. The OTC is hosted at the NORCE Norwegian Research Centre (NORCE) in Bergen, Norway, The National Oceanography Centre (NOC) in Southampton UK and the Universities of Exeter and Bergen. The OTC has five core workstreams focussed on 1) Leadership and management, 2) Labelling, 3) Training and Support, 4) Data and 5) New technology. Highlights in each area are as follows

1) Leadership and Management

(Richard Sanders & Erik Sandquist, NORCE, Andrew Watson & Jessica Thorn, Exeter).

Our major activity in 2020 was the initiation of an activity focussed on achieving a transformation in funding for ocean C observations away from research to operational funding streams (www.IOCOS.org). This involves working with a range of international partners including the Global Ocean Observing System (GOOS), the International Ocean Carbon Coordination project (IOCCP) and the Global Carbon project (GCP). It was stimulated by the insecure and inadequate nature of the funding streams supporting carbon observations documented in a variety of locations. Major activities include i) a launch at the ICOS science conference and the associated establishment of a website and twitter feed, ii) the submission of a comment/ opinion piece to Nature/ Science in spring 2021, iii), a major meeting in Spring 2022, probably at JPI Oceans, to develop a strategic blueprint and iv) an engagement plan with the COP in 2021.

2) Labelling

(lead, Ingunn Skjelvan, NORCE).

In 2020 we completed labelling operations on the stations DE-SOOP Polarstern and NO-SOOP Kronprins Haakon. In 2020 we also participated in a joint multi-mission survey as one of 12 European institutions where unmanned vessels (Saildrone - ATL2MED Mission) collected data in the Atlantic and Mediterranean Sea. The main aim for OTC has been to test the concept of using an unmanned surface vehicle as a reference CO₂ system and compare with FOS measurements. OTC aims to use a subset of the ATL2MED data in the evaluation of four of the current ICOS ocean stations in the Mediterranean Sea. This mission started in November 2019 and lasted until July 2020. This was a pilot study where useful information from remote stations were collected. Currently the data are going through quality control, which will take some time.

3) Training and Station support

(lead, Tobias Steinhoff, NORCE).

Our major planned activities for 2020 were impacted seriously by COVID, which lead to the MSA sessions during which training is normally delivered being moved online, an online data processing workshop being planned for November 2020 and the intercalibration exercise planned for summer 2020 in VLIZ being moved to 2021. We took the opportunity of the COVID lockdown to thoroughly evaluate our training portfolio in consultation with international partners and the MSA and presented this for approval at the virtual MSA in June. This plan contains both externally facing and internally facing elements; we will commit to regularly working with the IOCCP and SOLAS international programmes to ensure that ICOS station PIs and staff have the opportunity to experience international training events,

engage in the ICOS summer school and deliver bespoke support to ICOS stations at MSA events. In terms of station support, we spent much of 2020 setting up the infrastructure for the Gas Bottle calibration scheme approved by the GA in Autumn 2019 in Helsinki and are now developing a parallel scheme for membrane sensor based stations.

4) Data

(Benjamin Pfeil and Steve Jones, UiB).

In 2020 we supported all stations in returning their data to SOCAT and the Carbon portal following the Data Life Cycle document from the third quarter of 2018. We completed QuinCe development for SOOP-CO₂ and began migrating the stations' workflow to incorporate QuinCe, focussing on some SOOP-CO₂ stations in 2020, demonstrating a NRT capacity. Near Real Time data processing is now fully operational for labelled SOOP stations where satellite links are available to transmit data to shore, with automatic daily updates to L0 and L1 data in the Carbon Portal. In 2020, we have been involved in the ATL2MED mission where unmanned surface vehicles have been used in Atlantic and the Mediterranean Sea. We have processed the carbon data from the unmanned vehicles using QuinCe and made them available at the Carbon Portal.

5) Technology

(lead Socratis Loucaides, NOC).

Work in 2020 was heavily impacted by the COVID pandemic. We had aimed to development and integrate of new sensors for the determination of DIC, TA and pH on a number of autonomous platforms including the Autosub Long range, Kongsberg Seaglider, Liquid Robotics, Waveglider and profiling floats through the NERC funding (projects: CarCASS, CLASS). This work was partially successful however field activities virtually ceased and will instead be run in 2021. We took advantage of the lockdown period to begin a desktop study regarding the production of a calibration platform for the membrane sensors on fixed ocean stations and will seek grant funding in 2021 to pursue this.

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

Highlights

- Through a DWD-CRL contract for services, additional funding enabled in-depth investigation of the fossil fuel CO₂ signal at the ICOS atmosphere class 1 station KIT.
- Final reassignment of the low-level-counting (LLC) working standard at the end of its service life resulted in excellent agreement between the LLC and AMS measurement methods. In the last two years before the reassignment, the two measurement methods diverged.
- After many years of negotiation and intervention by the German focal point and the stakeholder, Heidelberg University has made the CRL engineer permanent.

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

In 2020, eleven atmospheric ICOS class 1 stations provided integrated samples to the ICOS CRL. Additionally, we analysed integrated samples from the ICOS class 2 stations Izana, Trainou and Schauinsland, and the ICOS CRL pilot station Heidelberg. Samples from the non-ICOS station Mace Head have been analysed in addition. Mace Head and Izana are key stations for determining the marine ¹⁴CO₂ background concentration. The marine background can be used alternatively to the continental background estimate derived from the ¹⁴CO₂ measurements at Jungfraujoch station.

Due to COVID, the low-level-counting (LLC) sample throughput in 2020 had fallen to about 83% of the previous year. The reasons for this were, on the one hand, occupational health and safety measures that only allow one person per laboratory and, on the other hand, the greatly extended maintenance time for four low-level-counters which broke down during the beginning of the first COVID shutdown. In total, 314 European samples were analysed by low-level counting.

As outlined in the work plan for 2020, 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 EC, Canada). In total, 33 samples from the global network were analysed in 2020, mostly before the COVID crises began.

The internal ¹⁴CO₂ working standard “Wilhelm 20” used to calibrate the low-level counters between 2016 and 2020 was reassigned at the end of its service time. The reassignment was based on comparison measurements with respect to the primary standard Oxalic acid II (SRM 4990 C). Compared to the initial assignment of Wilhelm 20 in 2016, the final assignment is 1.3 ‰ higher. The comparison measurements between the working and the primary standard were conducted throughout the service time of the working standard. All low-level-counter measurements referring to this working standard have been re-evaluated and retrospectively corrected.

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

Personnel task 1: 24.0 PM

Radiocarbon analysis of CO₂ from flask samples (Task 2)

In 2020 still, only five ICOS atmosphere class 1 stations did send flasks to the CRL, which have all been processed and analysed. However, the number of flask samples from ICOS class 1 stations did increase significantly from 22 in 2019 to 253 in 2020. The increase was driven by an additional DWD-CRL contract for services to study the fossil fuel CO₂ concentration at the ICOS atmosphere station KIT. Furthermore, also in the VERIFY project, we sampled additional ¹⁴CO₂ samples at KIT station.

As described in the CRL work plan for 2020, free flask analysis capacity has been used for various purposes outlined in the work plan sections “Other activities” and “Projects and international collaboration”. A large part of the free capacity was devoted to the CRL pilot station to develop new sampling strategies and to test surrogate tracers for regional fossil fuel CO₂ estimation. In total, we analysed 290 flask samples collected at the ICOS CRL pilot station. Among other usages, these samples are used to test APO as a potential surrogate tracer for fossil fuel CO₂. We finalised the RINGO project by analysing another 74 flasks from the Paris and the Rhine-valley region, thereby fulfilling Deliverable 12. For the VERIFY project, we analysed 42 campaign-samples in addition to the before-mentioned 90 VERIFY flask samples collected at KIT station. VERIFY did cover for the AMS analysis costs of all its samples. For the ATTO project, 20 flask samples have been analysed. The project covers the analysis costs as well as the sample preparation cost. In total, despite COVID, we could increase the number of analysed flask samples from 314 in 2019 to 605 in 2020.

We continued our efforts to analyse a subset of the integrated $^{14}\text{CO}_2$ samples also by AMS for quality control purposes. Since 2017 we have been reporting a steadily increasing difference between the two measurement methods. The re-assignment of the low-level-counting working standard "Wilhelm 20" and the subsequent reprocessing of the low-level $^{14}\text{CO}_2$ data reduced the AMS-LLC difference to 0.4 ± 0.3 ‰ for the entire period between 2016 and 2020. Thus, confirming that after the reassignment, the two measurement techniques are in excellent agreement again.

The quality control measurements carried out at the extraction- and graphitisation-line (EGL) were, as well, ongoing in 2020. Based on oxalic acid 1 (SRM 4990 B) measurements, the international ^{14}C scale could be reproduced to 0.11 ± 0.24 ‰ for the AMS measurements between July 2017 to end of 2020. The internal quality control gases show for 2020 a reproducibility (1σ) between 2.3 and 2.6 ‰, highlighting a stable reproducibility over the last years.

Level-1 and Level-2 data have been transferred to the station PIs directly. No official flask dataset was released by the ATC yet but is expected for 2021. Thus, Deliverable 3 and 4 have been accomplished by manual data transmission.

Personnel task 2: 14.6 PM (not including 9.6 PM from projects)

Production of integrated CO₂ samplers (Task 3)

One new integrated sampler for LMP was produced but could not be delivered due to unsolvable administrative problems with the Italian procurement system. A solution is still being sought. Deliverable 5 has thus partly been completed.

Personnel task 3: 0.8 PM

Interaction with station PIs (Task 4)

CRL scientists participated in both virtual atmospheric MSAs (Deliverable 6&7). All $^{14}\text{CO}_2$ 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. In addition, since 2020, the CRL provides guidance to station PIs for selecting the flask samples for $^{14}\text{CO}_2$ analysis.

Personnel task 4: 2.4 PM

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

Activity and finance reports for 2019 (Deliverable 8), as well as the work- and the financial plan for 2021 (Deliverable 9), have been submitted to the HO in time. In 2020, additional time was devoted to preparing the ICOS evaluation and the ICOS management plan. S. Hammer participated in the virtual 12th and 13th GA as well as in both virtual RI COM face-to-face meetings in 2020. With very few exceptions, S. Hammer has participated in the regular monthly teleconferences of the RI COM.

Personnel expenditures: 3.6 PM

Other important activities

In 2020 the CRL operated the ICOS CRL pilot-station, including:

- 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)
- semi-continuous in-situ ^{222}Rn 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 10 was fulfilled.

Personnel CRL pilot station: 6.5 PM

Penelope Pickers was conducting and evaluating the APO measurements at the CRL pilot station on a 50% position until the end of June 2020. We kept the APO measurements running until February 2021, thus including a second winter heating period. Penelope is currently working on a manuscript to publish the findings of the urban APO-based fossil fuel estimates in comparison to the ¹⁴CO₂-based estimates. Deliverable 11 is delayed. The manuscript submission is now planned for summer 2021.

Personnel APO testing: 4 PM

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

Highlights

- Successful application of the flask sampling strategy: continuous measurements at KIT station in excellent agreement with flask samples analysed at FCL
- Successful implementation of algorithm for automated sample selection that qualify for fossil fuel quantification based on ATC near-real time atmospheric in-situ data evaluation
- long extension of FCL personnel contracts after the end of the first 5 year membership commitment period.

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

In 2020 the number of ICOS class 1 stations that have implemented the flask sampling strategy using the ICOS flask sampler has increased to eight. To improve the instrumental capacity utilisation the system has been upgraded to allow connection of 30 samples to the gas chromatographic system (Deliverable 1). Additional samples were analysed within FCLs involvement in RINGO and in further supporting tests to establish the ICOS flask sampling program summing up to 1559 samples (781 in 2019). Discussions with the ATC have resulted in an agreement on flask sampling and flask data file formats for data reporting, the flagging scheme and data versioning. Implementation of these specifications has started at both central facilities. Problems in the quantification of SF₆ that were reported for 2019 have been resolved and the affected previous measurements could be re-evaluated by hindsight with a modified standardisation scheme. In 2020 the detector for CO analysis developed significant noise with service repair being delayed by the COVID lockdown situation and staff change in the FCL team.

Analysis of supplement parameters (CO₂ stable isotopes and O₂/N₂ ratios) (Task 2)

As envisaged in the 2020 work plan the focus of Task 2 activities was to further complete the availability of the specified ICOS flask sampling equipment to all class 1 atmospheric stations and such enable the implementation of the ICOS flask sampling strategy. The main efforts and results in 2020 were:

- production of 10 additional flask samplers and air drying units (satisfying the needs of the atmospheric network), incorporating various detail design improvements based on user feedback
- delivery of the sampler for the PAL and SMR station and progressing purchase agreements for samplers dedicated for SAC, LMP, CMN, KRE
- software improvements; this includes the development of an interface protocol for the interaction between flask sampler and ICOS infrastructure based on requirements from an MSA working group (Milestone 2), the implementation of the ffCO₂ sample selection algorithm that is based on in-situ measurement information communicated by the ATC to the flask samplers that is now regularly used at several stations (Milestone 1)
- online support including trouble shooting and provision of software updates to all remotely accessible ICOS samplers

While a flask sampler technical user workshop had been organized for March 2020 it had to be cancelled on short notice. The intended emphasis of the workshop was practical training that is not possible within a virtual meeting. Therefore, the workshop had to be postponed to a time that allows pan-European travelling (Milestone 3).

Flask samples have been analysed for CO₂ stable isotopes (Deliverable 2). The delayed O₂/N₂ measurement program was brought to operation with setting up an automatized measuring instrument periphery that is adapting technology originally developed for the ICOS flask sampler. The new automated setup allows a higher reproducibility and a higher sample throughput rate. It detects common problems and reacts correspondingly. Automated measurement data storage and data processing traceability are intrinsically included.

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

Three new atmospheric stations have been equipped with standard gas sets in 2020 (RGL, SSL, ZSF) to enable their rapid labelling. Standard gas cylinders that have been consumed at operative ICOS stations were refilled. Additional standard gases are regularly needed for the FCL, CRL and ATC operations, and the ICOS internal and external quality control (QC) activities. Due to partial lockdown periods with reduced lab activities and in anticipation of a potential shutdown of the FCL throughout 2020 a reduced frequency of target measurements at stations had been agreed with the Atmosphere MSA to reduce the risk of exhausted standard gases in periods of interrupted standard gas supplies. Yet, this situation did not occur and a total of 137 real air standard gases in high pressure cylinders have been produced in 2020 for the ICOS atmospheric observations. (Deliverable 3)

After resolving responsibilities with the OTC and ICOS-ERIC 60 high-pressure cylinders were purchased and pre-conditioned to be used for the standard gas delivery to ICOS ocean SOOP stations. Additional operational details were clarified with the OTC and the first sets of ocean CO₂ calibration gases were produced (13 standards).

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

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

The data processing software for the spectroscopic analyzers was upgraded to enable the calibration of atmospheric *and* ocean standard gases that need to be related to different reference standards.

The WMO Central Calibration Laboratory (CCL) has not released the CO₂ X2019 scale revision in 2020 so Milestone 4 (reprocessing of CO₂ measurement results) is postponed to when the new CO₂ scale is available. The WMO CCL provided a pre-release of the revised assignments to the ICOS-FCL as an external review to assess the resulting impact by the update on the internal consistency of ICOS data. An excellent consistency is observed for recent laser spectroscopic based CCL assignments. In order to clarify suspected small biases in earlier NDIR based CCL assignments the entire set of ICOS WMO standard gases was returned to the CCL for a second CRDS based recalibration.

Six Replacement Sets are available for periods when stations return their standard gases for recalibration. In 2020 this has been used by the stations NO-ZEP, IT-CMN, EC-IPR, FR-PUY and FI-PUI (Deliverable 5)

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

The international QC activities have been retarded by the pandemic and staff availability situation. For both the “Sausage” - Flasks and “MENI” (MPI-EMPA-NOAA-ICOS) round robin programs the ICOS-FCL distributed and analysed each one set of comparison samples in 2020 (Deliverable 6). The FCL has also sent one set of comparison standards to NOAA as part of the WMO Round Robin 7 loop for hydrogen measuring laboratories. No samples have yet been distributed by NOAA for the WMO greenhouse gas round robin (Milestone 5).

The QC report was updated and made available on the FCL webpage considering the results from all internal and external QC activities conducted in 2020 (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 2019 has been submitted to the HO in Feb 2020, the budget and work plan for 2020 were provided in October 2020. Additional time was devoted to contribute to the preparation of the ICOS management plan and the FCL input was provided to the Head Office according to their specifications. Updates on FCL activities were also presented at the General Assemblies and an FCL representative was participating at the General Assembly in May 2020.

Interaction with station PIs (Task 7)

The FCL scientists participated at the virtual ICOS Atmosphere MSA in June 2020. The reports on FCL activities were put up for discussion. A flask sampler user feedback session was providing useful input for further optimizations in the implementation of the flask sampling activities. 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).

Monitoring station Assemblies (MSAs)

For MSA meetings, see summary of meetings on page 59.

Atmosphere MSA Highlights

- Release of level2 data of 26 atmospheric stations (62 vertical levels) in September 2020, <https://doi.org/10.18160/H522-A9S0>
- As part of the drought-2018 initiative and associated data analysis, a homogenized dataset of historic CO₂ concentration data from 48 atmosphere ICOS and non-ICOS stations (96 vertical levels), with information going back to as early as 1971, was released, <https://doi.org/10.18160/ERE9-9D85>
- ICOS atmosphere data are currently used by the Copernicus Atmosphere Monitoring Service for evaluating its global forecasting system (<https://global-evaluation.atmosphere.copernicus.eu/co2/ghg/insitu-icos>)
- 3 atmospheric stations were approved as labelled ICOS stations in 2020 (now 26 in total).
- The ICOS Atmosphere Station Specifications Document, which is the central document defining the technical requirements for ICOS Atmosphere Stations, was revised and was released as version 2.0 in September 2020, <https://doi.org/10.18160/GK28-2188>

Ecosystem MSA highlights

- 2018 drought study, for which 35 stations provided data, was published in Philosophical Transactions of the Royal Society - B. Several station PIs and other ICOS ecosystem staff were authoring the papers in the special issue.
- 2 class 1 ICOS ecosystem stations and 5 class 2 stations were labeled and entered operational phase. Also 5 associated stations were labeled.
- Release of level 2 data from 3 Class1 stations and 5 Class 2 stations.

Ocean MSA highlights

May 2020: Establishment of the Station Ring Around in the Ocean community. This provided information to OTC and ERIC on the situation of the stations. This survey highlighted issues with funding and in most recently the impacts of covid.

Significant highlights

- Participation of 4 FOS stations in saildrone ATL2MED mission
- Enhanced interaction between OTC and MSA chairs and consequently MSA community. The main aim is to enhance the collaboration between OTC and MSA and improve the support that OTC is delivering to the stations. On that note it needs to be mentioned that stations have started benefiting from the existing support mechanisms that OTC and ERIC are providing, such as standardized calibration gases, calibration of sensors, use of jupyter notebooks, etc.
- Participation of Ocean PIs in the Warm Winter 2020 initiative.
- Stronger presence of Ocean PIs in the ICOS Science Conference (Sep 2020)
- Strong presence of ICOS PIs in GCB 2019 (published in 2020)

ICOS National Networks 2020

In addition to the actions described below, the national networks have contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Belgium

In addition to the actions described below, the ICOS Belgium has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

Funding obtained:

- After a funding of 8 years (2013-2020) during which ICOS-WB brought two stations to the ICOS label, the Walloon Region has granted ICOS-WB a new 5-years funding starting in 2021. This will allow to bring the third station to the label and to provide ICOS data for all three stations.
- Flemish stations were funded via the 2020 Research Foundation-Flanders International Research Infrastructure call (FWO IRI). Funding was obtained for four years (2021-2024) for the ecosystem stations of Brasschaat, Lochristi and Maasmechelen (University of Antwerp), the ocean stations Simon Stevin and Thornton Buoy (VLIZ) and a brand new associated ecosystem station in Yangambi in the Democratic Republic of Congo (University of Ghent).
- The Belgian Federal ocean station RV Belgica and atmospheric station at Reunion Island obtained funding for until the end of November 2021.

Network expansion:

- University of Ghent has joined ICOS Belgium as a new partner. UGent has constructed and will operate CongoFlux (PI Pascal Boeckx), a new associated ecosystem flux tower in the Democratic Republic of Congo.

Network activities:

- BIRA-IASB hosted the ICOS Atmosphere Monitoring Station Assembly (MSA) during 8-10 June 2020. The meeting was organized as a virtual event.
- Finalized the work done on scientific and technical concept for the integration of ground-based greenhouse gas remote sensing into ICOS as part of RINGO H2020 project. The corresponding report including the associated costs is available via this link: <https://www.icos-cp.eu/sites/default/files/2020-04/D1.5.%20Scientific-technical%20concept%20for%20the%20integration%20of%20European%20TCCON%20sites%20into%20ICOS%20and%20resulting%20costs.pdf>
- BIRA-IASB contributed to a document detailing specifications for high accuracy in situ vertical profile measurements. This document was submitted as RINGO H2020 deliverable and can be accessed via this link: <https://www.icos-cp.eu/sites/default/files/2021-1/D3.1.%20Specification%20for%20high%20accuracy%20in%20situ%20vertical%20profile%20measurements.pdf>
- Active participation in the ICOS drought 2018 task force – Vielsalm, Lonze and Brasschaat stations involved. Update 2020 : finalization of the participation which led to the publication

in September 2020 of three articles by Louis Gourlez de La Motte (the role of non-stomatal and stomatal processes on the assimilation of carbon by forests), Alexander Graf (altered energy partitioning across terrestrial ecosystems) and Zheng Fu (sensitivity of gross primary productivity to climatic drivers) in the special issue of the journal “Philosophical Transactions of the Royal Society”.

- Active participation in the Winter 2020 initiative – all Belgian ecosystem stations involved. This initiative is carrying out a study on the effects of the mild winter 2019-2020 on ice cover, gas and energy exchanges, sea and atmospheric currents and on yields for European ecosystems. The impact of the lockdown on solar radiation is also subject to analysis.

Data availability:

- ICOS Atmosphere Level 2 data from our station RUN located at Ile de La Réunion is now available via Carbon Portal. [doi:10.18160/X22K-CP0G](https://doi.org/10.18160/X22K-CP0G)
- The Near Real-Time data can be accessed via this link: https://data.icos-cp.eu/portal/#%7B%22filterCategories%22%3A%7B%22project%22%3A%5B%22icos%22%5D%2C%22theme%22%3A%5B%22atmosphere%22%5D%2C%22station%22%3A%5B%22iAS_RU_N%22%5D%7D%7D
- VLIZ Station BE-FOS-Thornton Buoy level 2 data are available in CP (<https://data.icos-cp.eu/portal/#%7B%22route%22%3A%22metadata%22%2C%22id%22%3A%22n94jijAEWH95fMNn8Mwd4l0M%22%7D> PID: [11676/n94jijAEWH95fMNn8Mwd4l0M](https://doi.org/10.11676/n94jijAEWH95fMNn8Mwd4l0M)). Data were also submitted to SOCAT v2021.
- VLIZ station BE-SOOP-Simon Stevin has started step 2 of labelling and expected to receive label in May 2021 GA. NRT data from the station are available in the ICOS CP (<https://data.icos-cp.eu/portal/#%7B%22route%22%3A%22metadata%22%2C%22id%22%3A%22HxuGZ1YBuJlkMjVu9vblDkps%22%7D>). Data were also submitted to SOCAT v2021.
- Ecosystem Level 2 data from BE-Lon is available at <https://meta.icos-cp.eu/objects/z8dfTUi0mKBEXy-PFHnEe672>.

Changes in station network

- Stations completing labelling in GA meetings of 2020
 - Class 1: ecosystem station Brasschaat BE-Bra (PI Ivan Janssens)
 - Class 2: ecosystem station Maasmechelen BE-Maa (PI Marilyn Roland), ecosystem station Vielsalm BE-Vie (PI Caroline Vincke)
 - Associated: ecosystem station Lochristi BE-Lcr (PI Tim De Meulder)
- New PIs – Pascal Boeckx for CongoFlux (pascal.boeckx@ugent.be)
- New stations, stations changing e.g. Class1 to Associated, stations removed from network
 - Associated: ecosystem station CongoFlux (PI Pascal Boeckx) in Yangambi, Democratic Republic of Congo. Operated by Ghent University in collaboration with Congolese partners: Center for International Forestry Research (CIFOR), the Regional Postgraduate School for Integrated Planning and Management of Tropical Forests (ERAIFT), the National Institute of agronomic studies and research (INERA). Construction of the tower was completed in October 2020 with funding from DGD Belgium through the 10th EU Development Fund as part of the Yangambi Pôle Scientifique (YPS).

- The RV Belgica oceanic station equipment (AUMS - OceanPack) was moved from the current RV A962 Belgica to the new RV Belgica being built in Vigo, Spain.

Provided training

- Students who graduated 2020 using ICOS data
 - MSc thesis:
 - Strivay L: *Improvement of the energy balance within the TERRA-Ecotron cells*. MSc thesis. University of Liege, Gembloux Agro-bio Tech
 - Kumba Z: *Analysis of ozone deposition on a pasture*. MSc thesis. University of Liege, Gembloux Agro-bio Tech
 - de Meue G: *Modelling of net CO₂ and water vapour exchanges in a beech and Douglas fir forest and simulations under different climate scenarios*. MSc thesis. Catholic University of Louvain-la-Neuve
 - Choquet P: *Simulation of the growth and greenhouse gas emissions of a conventional crop rotation in Hesbaye - Evaluation of the STICS model and analysis of the impact of climate change*. MSc thesis. University of Liege, Gembloux Agro-bio Tech
 - PhD thesis:
 - Lognoul M: *N₂O exchanges by three agricultural plots in Southern Belgium: Dynamics and response to meteorological drivers and agricultural practices*. PhD thesis. University of Liege, Gembloux Agro-bio Tech
 - Dumortier P: *Study of soil-atmosphere interactions in a grazed grassland*. PhD thesis. University of Liege, Gembloux Agro-bio Tech
- Organized training events, nr. of participants.
 - First ICOS OTC pCO₂ instrumentation inter-comparison. The event would have taken place in VLIZ facilities in Ostend, however had to be postponed because of the COVID-19 pandemic. This will take place in June 2021

Joint use of ICOS stations

- Other projects and organizations which use the facilities if any
 - Both VLIZ ICOS stations BE-FOS-Thornton Buoy and BE-SOOP-Simon Stevin are used in ICOS and LifeWatch.
 - Use of VLIZ ICOS capacity on FWO project on Enhanced Silicate Weathering (ESW)
 - Forest Flow (BELSPO): Estimation of dissolved organic compounds flows at the scale of the plot and the watershed (UAntwerp, KUL, UCL, IRM): Vielsalm and Brasschaat stations involved
 - ACRVF (DGO3, SPW): Assessment of water stress in the soils of the Walloon forest: best estimate of extractable water: Vielsalm station involved
 - Actris RI (road map ESFRI 2016): "Aerosols, clouds and trace gases European research Infrastructure" with BIRA, KMI, IsseP, Ulg: Vielsalm station involved à Implementation step (=>2024). Installation on the site of a PTR-(TOF)-MS and a MAX-DOAS (Airyx SkySpec system)

- COST action « GHG-AGRI »: “Strategies to reduce greenhouse gases agricultural emissions: a European farmers’ perspective”, Proposal Reference OC-2020-1-24569: Dorinne and Lonze stations involved (WP1 (Emissions from the livestock sector) and WP2 (Agricultural N₂O, CH₄ and NH₃ emissions))
- Project NAPERDIV - Biodiversa climate change - <http://www.biodiversa.org/1785>: Lonze station involved (improved calibration of STICS on GHGs)
- Project SoilTemp : an initiative aiming at mapping soil health in agricultural systems using DNA-analysis of soil microbial communities - Lonze station involved
- The Maasmechelen ecosystem station is closely linked with the ECOTRON Hasselt University (AnaEE). The ICOS tower provides the necessary data to control the environment in its chambers.
- BIRA-IASB co-authored a report on European greenhouse gas column cal/val network sustainability. The report was part of an European Environment Agency’s (EEA) study focusing on implementation of cross-cutting activities for coordination of the in-situ component of the Copernicus Programme Services. The report can be accessed via this link: <https://insitu.copernicus.eu/library/reports/InSituReportGHGnetworkssustainabilityv1.0.pdf/view>
- BIRA-IASB is part of a H2020 project titled CCVS – Towards a Copernicus Calibration and Validation Solution (<https://ccvs.eu/>). We will contribute to the Atmospheric component of the cal/val solution. We are the lead for several work packages and contribute to several other work packages in the project.

Czech Republic

In addition to the actions described below, the ICOS Czech Republic has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

Tower construction of CzechGlobe Tropical GHG station in Ghana following some of the the ICOS protocols

Changes in station network

No changes.

Provided training

- Students who graduated 2020 using ICOS data
 - Bc. Tomáš Ghisi – Master Thesis *Monitoring evapotranspirace a stresu suchem s využitím satelitního snímkování* (Monitoring of evapotranspiration and drought stress using remote sensing), Mendel University in Brno, Faculty of Agriculture, 2020
 - Mgr. Barbora Veselá – Dissertation Thesis *Kombinovaný vliv sucha, UV záření a koncentrace CO₂ na buk lesní a vybrané druhy horského lučního ekosystému* (Combined effect of drought, UV radiation and CO₂ concentration on European beech and selected species of the

mountain grassland ecosystem), Mendel University in Brno, Faculty of Forestry and Wood Technology, 2020

- Ing. František Jurečka – Dissertation Thesis *Evapotranspiration estimation using remote sensing tools*, Mendel University in Brno, Faculty of Agriculture, 2020
 - Richard Azu Crabbe – Dissertation Thesis *Exploring the potentials of satellite remote sensing for carbon monitoring in European forest systems*, Mendel University in Brno, Faculty of Forestry and Wood Technology, 2020
 - Mgr. Ing. Monika Koróniová, Ph.D. – Dissertation Thesis *Získavanie priestorových informácií pomocou snímokovania a laserového skenovania. Hyperspektrálne snímokovanie ako komplementárny nástroj archeologickej prospekcie* (Collecting spatial information using imaging and laser scanning. Hyperspectral imaging as a complementary tool for archaeological prospection), Masaryk University, Faculty of Philosophy, 2020
 - Bc. Lukáš Slezák – Master Thesis *Využití hyperspektrálního DPZ v urbánním prostředí* (Use of hyperspectral Remote Sensing in Urban Area), Masaryk University, Faculty of Science, 2020
- Organized training events, nr. of participants.
 - Annually is given in average 40 lectures (during 2020 were instead of physical a few on-line) for the general public (among others the Week of Science and Technology organised annually by CAS). The very important part of the lecturing and training activity are lectures to specific groups such as companies' managers (e.g. energy company ČEZ a. s.) or policy-makers (e.g. government, regional authorities, municipalities).
 - Excursions for students in Bc. and MSc. study programmes, experts, and/or organisations involved in research and development are regularly organised. There are approximately 20 CzeCOS excursions per year, however due to COVID-19 during the year 2020 only a few were organised. Moreover, excursions for the general public are organised during so-called "LRI open days" including excursions within Week of Science and Technology etc. organised by CAS, CzechGlobe itself, and/or local authorities for requests.
 - Organisation in collaboration with ICOS ERIC (ICOS HO) of the RINGO webinar for ICOS partner and candidate countries on 5th October 2020. The training webinar was mainly dedicated to ICOS latest development and national research infrastructure roadmap evaluations.

Denmark

In addition to the actions described below, ICOS Denmark has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

ICOS Denmark has been fully occupied with bringing the stations up to ICOS standard in view of getting all main stations and most of the associated stations classified in 2021. Another main activity has been to identify potential funding sources for the ICOS/DK operational phase starting late 2021. For this means, a short brochure describing the Danish station network has been produced. The brochure describes the reasoning for having GHG measurements in Denmark and possible extensions of the network in preparation for a verification system for GHG emissions. This includes the wish for two new atmospheric stations (one at the west coast of Denmark and one at the Risø Campus (eastern Denmark),

as well as plans for a national competence centre facilitating and promoting the use of ICOS data for the benefit of the Danish society.

Changes in station network

- Thomas Friberg (University of Copenhagen) replaces Kim Pilegaard (Technical University of Denmark) as National Focal Point for Denmark as of January 1, 2021.
- One associated station, GL-Kbf, was removed from the network, due to the difficulty in making this particular station to comply with ICOS standards.

Provided training

- The DK-SOR station is utilized in bachelor and master education.

Joint use of ICOS stations

- The atmospheric station in Greenland (SNO) is co-utilized by ICOS and ACTRIS.

Finland

In addition to the actions described below, ICOS Finland has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

Changes in station network

- Stations completing labelling in GA meetings of 2020
 - Lake Kuivajärvi received associate ecosystem station label in May 2020
- No new PIs or changes in station network

Provided training

- Students who graduated 2020 using ICOS data
 - Korkiakoski, M., 2020: *The short-term effect of partial harvesting and clearcutting on greenhouse gas fluxes and evapotranspiration in a nutrient-rich peatland forest*. PhD thesis in Meteorology, Finnish meteorological institute/ University of Helsinki.
 - Miettinen, H., 2020: *Spatiotemporality of carbon fluxes along a boreal land-stream-lake continuum*. PhD thesis in Environmental Sciences, University of Helsinki.
- Organized training events, nr. of participants.
 - Eddy covariance intensive course (5 ECTS, 25 participants), 27-31.01.2020, Kumpula Campus, University of Helsinki
 - Field course on micrometeorology and hydrology (5 ECTS, 26 participants), 21.-25.9.2020, Hyytiälä forestry field station, University of Helsinki

- Advanced analysis of atmosphere-surface interactions and feedbacks (5 ECTS, 50 participants), 2.-13.3.2020, Hyytiälä forestry field station, University of Helsinki

Joint use of ICOS stations

- Other projects and organizations which use the facilities if any
 - Several projects within Institute for Atmospheric and Earth System Science (INAR) that use ICOS data and/or facilities, such as CarboCity project funded by the Academy of Finland and led by Assoc. Prof. Leena Järvi, CO-CARBON funded by Strategic research council and led by Assoc. prof. Leena Järvi, Role of upland forest soils in regional methane balance: from catchment to global scales (UPFORMET) (2017-2021, led by assoc. prof. Annalea Lohila and funded by the Academy of Finland), Carbon dynamics in Arctic: past, present and future (CAPTURE) (2016-2020, funded by the Academy of Finland and BIBIFE project granted by Academy of Finland and led by prof. Jaana Bäck.

France

In addition to the actions described below, ICOS France has contributed to the highlights of entire -RI (page 4), and to the publication list (annex 2) with 127 articles

Highlights

- The COVID19 lock-down in Spring and Fall did not stop French ICOS registered stations, ATC or ETC activities but led to postpone maintenance activities since some stations could not be accessed as usual. Non ICOS stations associated with the ICOS France consortium were more affected, for instance the annual measurement campaign in the Mediterranean sea was canceled. The annual French ICOS scientific and technical assembly could not be organised in March 2020 as planned since this 3-day meeting requires a physical attendance. It was therefore postponed to 12-15 October 2021 and will be held in the University of Reims Champagne Ardennes where a new atmospheric station is being prepared by the research unit GSMA (Dr L. Joly).
- The French atmospheric station network led by Michel Ramonet has proposed swiftly a diagnostic about the impacts of events such as drought and heatwave or COVID 19 lock-down on the atmospheric concentrations of greenhouse gases in urban environments. A synthesis on lock-down impacts on the atmosphere was published e.g. as a special report of the Atmosphere thematic group of the French consortium of research institutes (ALLENVI, <https://www.allenvi.fr/groupe-thematiques/atmosphere/actions>).
- The French network was strongly involved in the projects RINGO (Atmospheric measurements onboard of ships, Ecosystem network optimisation, analysis of legacy data, TCCON data processing) and ENVRI-FAIR as well as in the Drought 2018 (9 articles) and Winter2020 initiatives (Dr A. Tang's post doctoral project on lock down effects on ecosystem-atmosphere exchanges). The French network has also contributed to various sessions of the ICOS Conference in 2020. The Atmospheric centre hosted at Saclay was involved in the development of sensors dedicated to urban environments, FTIR measurements intercomparison, flask sampling strategy and other activities (Rn measurements dataflow, data formatting, aircores data processing etc.).

Changes in station network

- There was no significant changes in the atmospheric and ocean domains station networks.
- Three additional Ecosystem stations completed the labelling process and were acknowledged by the ICOS-RI GA in 2020: the cropland sites Auradé (FR-Aur, associated, PI: T. Tallec), Lamasquère (FR-Lam, Class 1, PI: A. Brut) and the grassland site Méjusseaume (Fr-Mej, associated, PI: C. Flécharde). The infrastructure (towers) of the rainforest station at Nouragues (GF-Nou, associated, PI: J. Chave) had to stop operations for safety reasons and the station has been suspended until further notice.
- Daniel Berveiller is replacing Eric Dufrêne as Fr-Fon station PI in 2021. Emilie Joetzer has been recruited in October 2020 at INRAE Nancy as scientist. She will be involved in the research activities and management of the FR-HEs Class 1 Ecosystem station.
- The French network is expected to be entirely labelled in 2021, with 5 remaining stations to be proposed for labelling.

Provided training

In 2020 four PH D dissertation thesis and 6 Master thesis in relationship with the French ICOS network were presented. Ph D. thesis are listed at the end of this chapter. The ICOS France community has organised a series of service and facilities allowing mutual and self-training (forums, webinars) managed by engineers, technicians and scientists.

Joint use of ICOS stations

- A national project funded by ANR and coordinated by F. Lohou (CNRS, Toulouse) has been launched in 2020 with the objective of upscaling surface-atmosphere flux from plot to sub-regional scale. This project will offer the opportunity to coordinate measurements and modelling activities at site co-located with the ACTRIS infrastructure in France.
- Within the RINGO project, atmospheric measurements were set onboard of research ships in order to sample atmospheric GHG concentrations near the ocean surface.

The following Ph D thesis were successfully presented in 2020:

- Iris Le Roncé: "*Déterminisme environnemental de la fécondité du chêne vert*", soutenue le 12 novembre 2020 sous la direction de Isabelle Chuine, Jean-Marc Limousin et Samuel Venner, Université de Montpellier.
- Laura Garcia de Jalon: "*Exploring the effects of microhabitat, ectomycorrhiza and epigenetic regulation on the establishment and performance of holm oak (Quercus ilex L.) in a drier world*" soutenue le 11 décembre 2020 sous la direction de Franck Richard, Alexandru Milcu et Jean-Marc Limousin, Université de Montpellier
- Gonzaga-Gomes L., 2020. "*Echanges de composés volatils biogéniques entre l'atmosphère et les cultures de blé, maïs et colza*". Thèse de Doctorat, Sorbonne Université Jussieu Paris, UMR INRA AgroParisTech EcoSys Grignon, Université Paris-Saclay, soutenue le 17 février 2020.
- Laurent Bigaignon, 2020. "*Etude de l'impact de la variabilité climatique et de la pression anthropique liée à l'agriculture sur les émissions de N₂O*". Université Paul Sabatier, Toulouse 3.
- Msc thesis successfully presented in 2020:

- Ariane Don. *Signature isotopique du CO₂ émis par les plantes de zones humides* (revue bibliographique). Université d'Orléans.
- Florian Jarry. *Effet de la végétation sur les flux de GES dans une tourbière dans un contexte de restauration écologique*. Université d'Orléans.
- Syrine Noucier. *Analyse des mesures de CO₂ et CH₄ à bord du navire COLIBRI (Atlantique, Méditerranée et côtes européennes)*. Master ICE, Université Versailles St Quentin / Université Paris Saclay.
- Hugo Treuil-Dussouet. *Etude de la phénologie de la végétation sur le réseau international PhenoCam : Analyse du lien entre la variabilité de la date de débourrement intra-population et les variables climatiques* Université Paris-Sorbonne.
- Lilian Vallet. *Modélisation de la dynamique intra-populationnelle du débourrement en Ile-de-France*. Université Paris-Saclay
- Mubarak Mahmud. *Nitrogen and biomass repartition in oak tree (Quercus petraea)*. Université Paris-Saclay.
- Quentin Hamzaoui. *Suivi dynamique de la croissance du colza assisté par télédétection satellitaire et modélisation*. M2 Géomatique, Université Paul Sabatier Toulouse 3.
- Augustin Tommasini. *Apport de l'hyperspectral dans la détection de stress hydrique de systèmes cultivés*. Stage Ingénieur ISAE, Toulouse.

Germany

In addition to the actions described below, ICOS Germany has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

- Unique all-year $p\text{CO}_2$ measurements in the Arctic Ocean on free drifting DE-SOOP Polarstern during the international Arctic expedition MOSAiC
- All-year $p\text{CO}_2$ measurements in moorings installed for 24 months (mid 2019 till mid 2021) at the LTER (Long-Term Ecological Research) Observatory HAUSGARTEN in Fram Strait
- Network-wide contribution to Special Issue on European drought 2018 (see Highlights, p.4)
- Official retirement farewell ceremony for PI Christian Bernhofer (Sep 2020)
- Design of a Saxonian carbon monitoring concept for LfLUG (Landesamt f. Umwelt, Landwirtschaft und Geologie)
- Internal cooperation, e.g. TU Dresden with Landesforst Brandenburg on DE-Kie station
- Participation and contribution on proposals (TerraNet, IMPACTER, CDR)
- Contributions to EU proposal PAUL on city observatories
- Close collaboration with the South African Ecological Observation Network (SAEON) to help establish further CO₂ eddy-covariance towers in South Africa within the project EMS Africa (Ecosystem Management Support for Climate Change in South Africa)
- Installation and successful operation of the new Licor CO₂ sensor LI-7815 on the GEOMAR SOOP line in the North Atlantic (DE-SOOP-Atlantic Sail). The sensor has the potential to require

fewer calibration gases and thereby increase the interval between standard gas runs, while at the same time increasing the accuracy of measurements. Based on the testing period necessary instrument changes are currently discussed with Licor.

- First year of operation of the new installation on DE-SOOP-Finnmaid in November 2019, now featuring pCO₂, pCH₄, pN₂O, pO₂, and spectrophotometric pH_T measurements across the Baltic Sea between Lübeck and Helsinki.

Changes in station network

- Stations completing labelling in GA meetings of 2020
 - Ocean network
 - DE-SOOP Polarstern was labelled as Class 2 station, PI: Mario Hoppema (AWI)
 - Atmosphere network
 - Helgoland (HEL) tower was labelled as Class 2 station, PI: Dagmar Kubistin (DWD)
 - Ecosystem network
 - Forest site Tharandt (DE-Tha) was labelled as Class 1 station, PI: Christian Bernhofer (TU Dresden)
 - Crop site Gebesee (DE-Geb) was labelled as Class 1 station, PI: Christian Brümmer (Thünen Institute)
 - Forest site Hainich (DE-Hai) was labelled as Associated station, PI: Alexander Knohl (Göttingen University)
- New PIs and new stations that officially joined in January 2020 were already listed in the 2019 report

Provided training

- Students who graduated 2020 using ICOS data
 - Andréa Mesquite and Dieu Anh Dinh, graduates of Nippon Foundation-POGO Centre of Excellence at the Alfred Wegener Institute, Helgoland
 - 3 B.Sc. Theses at University of Freiburg, Chair of Environmental Meteorology
 - Jannik Vikari: *Beurteilung des Schädigungsgrades von Waldkiefern anhand der Baumkronentemperatur unter Verwendung einer drohnengestützten Wärmebildkamera* (Supervised by Prof. Dr. Andreas Christen, Chair of Environmental Meteorology, co-supervised by Prof. Dr. Matthias Dees).
 - Katja Kröner: *Phenocam-Beobachtungen in einem dürrgeschädigten Kiefernwald im Jahrestag und deren Beziehungen zu CO₂-Flüssen sowie Radialveränderungen* (Supervised by Prof. Dr. Andreas Christen, Chair of Environmental Meteorology, co-supervised by Prof. Dr. Hans-Peter Kahle).
 - Naomi Vöhringer: *Veränderungen des Nettoökosystemaustauschs im Hartheimer Wald* (Supervised by Prof. Dr. Andreas Christen, Chair of Environmental Meteorology, co-supervised by Prof. Dr. Markus Hauck).

Joint use of ICOS stations

- Within KliMoBay Project (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):
 - Use of data by the project partners of Ludwig-Maximilians-University Munich (LMU) and Technical University of Munich (TUM)
 - Study on UAV surveys at the eddy covariance station by Augsburg University, Water and Soil Resource Research
- In the framework of a PhD thesis, the Geographical Institute of the University of Aachen performed and published a spatiotemporal dataset of CO₂ fluxes throughout the Rur catchment, using a machine-learning approach (random forest) to combine satellite remote sensing data with fluxes of 9 partly temporary eddy-covariance stations in the catchment operated by ICOS member institution Forschungszentrum Jülich (IBG-3). These include the three ICOS sites DE-RuS, RuR and RuW, and FLUXNET data from 6 further German stations that were used for model training, including the ICOS sites DE-Geb, DE-Hai, DE-Tha and DE-Gri.
- Cosmic Sense measurement campaign at the TERENO/ICOS site Wüstebach – The project "Cosmic Sense", funded by the German Research Foundation, carried out a measurement campaign of several weeks at the TERENO/ICOS site Wüstebach in autumn 2020 to record soil moisture and its changes over a wide area. For this purpose, 15 stationary cosmic-ray neutron sensors and a mobile cosmic-ray rover were deployed to record the spatial distribution of soil water and to investigate how precipitation, evaporation, and deep percolation affect both soil moisture and plant water storage in a catchment area. Drones and a gravimeter were also used. The results should help not only to better understand the processes of the water cycle, but also to optimize hydrological models. In addition to Research Centre Jülich, the University of Potsdam, the Technical University of Berlin, the University of Heidelberg, the Helmholtz Centre Potsdam, the Karlsruhe Institute of Technology and the Helmholtz Centre for Environmental Research were involved.
 - DFG Project Cosmic Sense, <https://www.uni-potsdam.de/de/cosmicsense/>
- New project funded "Digital Forest: A real-time forest monitoring system for climate change impacts" (funded by the Ministry of Science and Culture of the State Lower Saxony)
- Atmosphere station KIT: Radon instrumentation and source apportionment with NO_x as anthropogenic tracer by University of Heidelberg
- Ecosystem forest stations as ICP Forests Level II sites
- Joint use of ICOS stations DE-Tha, DE-Gri, DE-Kli in the project "Carbon storage and release in soils under agricultural and forest use" funded by Saxonian LfULG (Aug 2018 - Jul 2020)
- DE-Geb site and data used for research campaign and analysis by Max-Planck Institute Jena in a study on sun-induced chlorophyll fluorescence (SIF) of plant canopies as a measure of plant photosynthetic capacity
- Joint use of Helmholtz/TERENO sites within MOSES campaigns and CosmicSense project
- DFG project "Do wind-induced pressure fluctuations contribute to methane oxidation in aerated soils?" funded by the German Research Foundation (DFG, 2019-2022) to Prof. Dr. D. Schindler, Uni Freiburg. For more information, see <https://www.meteo.uni-freiburg.de/en/research/pressure-pumping-and-methane-oxidation>

- INTERREG EU Project Clim'ability design: Testing of mobile sensors to measure heat stress, heat stress monitoring inside forest.
 - <https://www.meteo.uni-freiburg.de/en/research/climability-design>
- ERC Synergy Grant "Urbisphere" - Calibration and testing of instruments, in particular deployment of wind LIDAR for testing purposes.
 - <https://www.meteo.uni-freiburg.de/en/research/urbisphere>
- Within the BMBF collaborative project DARGO2025, the GEOMAR SOOP line crossing the North Atlantic (DE-SOOP-Atlantic Sail) will serve as a reference for surface measurements of biogeochemical Argo floats featuring pH sensors. The floats will be deployed in 2021, but first case studies were performed in 2020.

Other event

- Uwe Eichelmann, the technician at TU Dresden for ICOS data acquisition setups, data manager and measurement expert for decades back to the first EC measurements of the department in the 1990ies, passed away in the beginning of 2021. The ICOS infrastructure of the Department of Meteorology is one of his valuable legacy.

Italy

In addition to the actions described below, ICOS Italy has contributed to the highlights of entire -RI (page 4), and publication list (annex 2).

Changes in station network

- **Stations completing labelling in GA meetings of 2020:**
 - a) **Stations having received the ICOS label in May 27, 2020**

Class 2 Atmosphere Station Lampedusa (Lmp); *Responsible Institution:* National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA); *Station PI:* Alcide di Sarra
 - b) **Stations having received the ICOS label in November 17, 2020**

Associated Ecosystem Station Lison (IT-Lsn); *Responsible Institution:* University of Padova and University of Udine; *Station PI:* Andrea Pitacco
- **New PIs:**

Antonello Provenzale, PI of the new candidate Associated Ecosystem Station Nivolet – Gran Paradiso Nation Park (IT-Niv)
- **New stations, stations changing e.g. Class1 to Associated, stations removed from network:**
 - a) **Stations changing from Class 2 to Associated**

Ecosystem Station Lison (IT-Lsn); *Responsible Institution:* University of Padova and University of Udine; *Station PI:* Andrea Pitacco
 - b) **New stations**

New candidate Associated Ecosystem Station Nivolet – Gran Paradiso Nation Park (IT-Niv); Italian Alps, 45.49091 – 7.13943, 2708 m a.s.l.; *Environment:* Alpine grassland; *Responsible Institution:* Institute of Geosciences and Earth Resources (IGG) of National Research Council (CNR); *Station PI:* Antonello Provenzale

Provided training

The training activities of the Italian network during 2020, although strongly penalized by the pandemic situation due to Covid-19, are reported below:

- **Students who graduated 2020 using ICOS data**
 - 1 student (IT-Cp2)
 - 1 student (IT-Niv)
 - 2 students (IT-Tor)
- **Organized training events, nr. of participants**
 - Guided tour of the ecosystem station IT-Cp2 for students of the degree course in "Landscape Ecology", Sapienza University of Rome (nr. of participants 15).
 - Training internship for a student of the Bachelor's degree in Biological Sciences at the University of Genoa "Study of the exchange of carbon dioxide at the water-air interface in the Miramare Protected Area in relation to the weather conditions" (IT-FOS-Miramare).
 - Virtual Seminar "The atmospheric component within the Research Infrastructure ICOS (Integrated Carbon Observation System) and the CNR – ISAC contribution", 20th May 2020 (nr. of participants 50).

Joint use of ICOS stations

- Other projects and organizations which use the facilities
 - National 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 (IT-BCi; IT-PCm; IT-Cp2; Lmp; IT-FOS-PALOMA; IT-CMN)
 - PNIR - National Research Infrastructure Program: "*Strengthening of the human capital of the Research Infrastructures*" (IT-BCi; IT-PCm; IT-Cp2; Lmp; IT-FOS-PALOMA; IT-CMN)
 - National Project PRIN EUFORICC (*Establishing Urban FORest based solutions In Changing Cities*) (IT-Cp2; IT-PCm)
 - LTER (*Long-Term Ecosystem Research*), INTERREG V-A France - Italy (ALCOTRA) AdaptMontBlanc (*Adaptation of the Territorial Planning to climate changes within Mont Blanc Space*), LIFE PASTORALP (*Pastures vulnerability and adaptation strategies to climate change impacts in the Alps*), ESA AlpSnow, INTERREG ITA-CH RESERVAQUA (IT-Tor)
 - OneForest project (European, without funding, approved); IBPRES (European, with funding, submitted) (IT-Ren)
 - 2020 Atlantic to Mediterranean Mission Saildrone ATL2MED (IT-FOS-W1M3A; IT-FOS-PALOMA; IT-FOS-EM23A; IT-FOS-Miramare)
 - MedCcCA (*Mediterranean Collaboration on Ocean Acidification*) Proposal for a COST Action submitted in December 2020 (IT-FOS-PALOMA; IT-FOS-Miramare)
 - National projects PULVIRUS (Lmp) and Ricerca di Sistema – RdS (IT-PRS)
 - H2020 project RINGO "*Readiness of ICOS for Necessities of Integrated Global Observations*" (Lmp; IT-FOS-Miramare; IT-FOS-PALOMA)

Netherlands

Norway

In addition to the actions described below, ICOS Norway has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

In October 2020 ICOS Norway presented results from the national network at the 'Open meeting on greenhouse gas emissions' in cooperation with the Norwegian Environment Agency (<https://www.miljodirektoratet.no/aktuelt/arrangementer/2020/oktober-2020/apent-moteom-klimagassutslipp/>). The meeting had around 60 participants and took place digitally. The purpose of the meeting was to improve collaboration between researchers and stakeholders (Ministries and Agencies in particular), enabling better exploitation of data produced by the national observing network for ICOS for use in emissions verification at the national and international level.

Changes in station network

- The major change for the ocean domain in this reporting period, is that the station NO-SOOP-Tukuma Arctica has replaced the station NO-SOOP-Nuka Arctica. The container vessel M/V Nuka Arctica, operated as a class 1 ICOS station by University of Bergen (SOOP-Nuka Arctica), was taken out of service and replaced by a new vessel M/V Tukuma Arctica in April/May 2020. This vessel operates on the same route as Nuka. NO-SOOPNuka Arctica produced data until April 2020 (recovery rate 65%). The installation on M/V Tukuma Arctica was severely delayed due to the Covid-19 pandemic (travel restrictions as the vessel only calls ports in Denmark, quarantine time for staff after coming back to Norway, delayed delivery of sensor parts due to closed calibration facilities). However, by January 2021 the station was operational and produced data. The next step towards certifying that the station maintains the quality assured by the labelling is to collect two months of high-quality data.
- Stephen Platt, Senior Scientist at NILU has been confirmed as PI at Zeppelin and Birkenes, replacing Cathrine Lund Myhre.
- Upgrades to Birkenes (ATM) required for class 2 label, including construction of 75 m mast and associated infrastructure/ training have been completed.
- Construction of a mast at Hurdal (TER) required for class 2 began at the end of 2020. The phase 2 of the labelling process has been officially opened November 12th, and the mandatory Webex seminar has been performed, implying a target data for the final approval of the labelling of November 2021.

Provided training

- Students who graduated 2020 using ICOS data: Rolf van der Vleugel, Quantification of the net effects of the 2018 European summer on regional CH₄ emissions in Fennoscandia, Wageningen University. (Master student –Internship at NILU).

Joint use of ICOS stations

- Most stations in the ICOS Norway network host projects, short-term campaigns, and national and international monitoring programmes.

Sweden

In addition to the actions described below, ICOS Sweden has contributed to the highlights of entire -RI (page 4), and publication list (annex 2).

Changes in station network

- From 2021 onwards, the mire station Mycklemossen (SE-Myc) in the Skogaryd catchment, north of Gothenburg and the SOOP line M/S Tavastland serving between Oulou in Finland and Travemünde in Germany will be officially joining ICOS Sweden. Both stations started the labelling process in 2020.

Provided training

- Phd course “From CO₂ in situ measurements to carbon balance maps as a tool to support national carbon accounting” run by the Department of Physical Geography and Ecosystem Science at Lund University Sweden with large contribution from ICOS Sweden and the Carbon Portal. The course was supported by ClimBEco and was included in the ClimBEco research school course program (CEC, Lund University, Sweden). The course aimed at introducing the concept of assessing the carbon balance of a geographical region from in situ measurements and how the results can be used as a tool to support national carbon accounting. (12 students)
- ICOS Sweden stations are actively included in courses at different levels (Bsc, Msc). During 2020 virtual tours to the sites have been organised to allow the students to “access” the stations. E.g.
 - LU, Msc, Biosphere-atmosphere interactions (9 students)
 - UU, Bsc, Geovetenskap - planeten Jorden (45 students)

Joint use of ICOS stations

Only mentioning other research infrastructures, not all projects using the stations

- ACTRIS – Aerosols, Clouds and Trace Gases research Infrastructure (SE-Nor ES+AS, SE-Htm ES+AS, SE-Svb ES+AS, SE-Oes FOS)
- Swedish Infrastructure for Ecosystem Science (SITES) – Swedish nationally coordinated infrastructure for terrestrial and limnological field research (SE-Svb, SE-Deg, SE-Sto, SE-Myc)
- BONUS Integral project, Integrated carboN and TracE Gas monitoRing for the bALtic sea, EU-BONUS (SE-Oes)

Switzerland

In addition to the actions described below, ICOS Switzerland has contributed to the highlights of entire -RI (page 4), the list of Outreach activities (annex 1) and publication list (annex 2).

Highlights

24.09.2020: ICOS Switzerland received funding for the next four years (ICOS-CH Phase 3, 2021-2024). This will ensure the continuation of the ICOS measurements at the two ICOS Class 1 stations Jungfraujoch and Davos and another four years as part of ICOS RI.

The 2018 drought synthesis paper of Gharun et al. (Special Issue Drought 2018) was taken up in several national and one international newspaper article. Datasets have been downloaded many times.

The full biomass inventory was accomplished at Davos station in autumn 2020.

Changes in station network

- Stations completing labelling in GA meetings of 2020: unchanged
- New Pls: Station PI of Davos station changed from Lukas Hörtnagl to Mana Gharun.
- New stations, stations changing e.g. Class1 to Associated, stations removed from network: unchanged

Provided training

- Students who graduated 2020 using ICOS data

Nicolas Winter (M.Sc. Umweltnaturwissenschaften), ETH Zurich. *Ecosystem service provision and multifunctionality of three major European land-use types.*

- Organized training events, nr. of participants.

Indonesian Meteorological Climatological and Geophysical Agency (BMKG) focus group discussion: Steinbacher, M., Long-term observations of atmospheric trace gases: challenges, implementation and operation, BMKG focus group discussion, virtual, November 12, 2020, about 100 participants.

Global Atmosphere Watch Training and Education Centre (GAWTEC) webinar: Steinbacher, M., The Importance of Quality Assurance and Quality Control for long-term in-situ atmospheric composition observations, GAWTEC webinar, virtual, December 07, 2020, 112 participants.

Joint use of ICOS stations

Davos station:

- Long-term Forest Ecosystem Research ([LWF](#))
- National Air Pollution Monitoring Network ([NABEL](#))
- The biological drought and growth indicator network ([TreeNet](#))
- [Swiss FluxNet](#)
- [FEVER](#)
- [SAPFLUXNET](#)
- [RINGO](#)

Jungfrauoch station:

- International Foundation High Altitude Research Stations Jungfrauoch and Gornergrat ([HFSJG](#))
- National Air Pollution Monitoring Network ([NABEL](#))
- Global Atmosphere Watch Programme ([GAW](#))
- [SwissMetNet](#)
- [EUMETNET E-PROFILE](#)
- Advanced Global Atmospheric Gases Experiment ([AGAGE](#))
- Aerosol, Clouds and Trace Gases Research Infrastructure ([ACTRIS](#))
- [RINGO](#)

United Kingdom

In addition to the actions described below, ICOS United Kingdom has contributed to the highlights of entire - RI (page 4), and publication list (annex 2).

Changes in station network

Ridge Hill atmospheric station has officially joined the UK National Network. It hopes to be labelled in 2021. The PI is Simon O'Doherty, University of Bristol, UK, for the Ridge Hill atmospheric station

The UK-Caribbean SOOP line has been removed from the network.

List of meetings and national science conferences

Atmosphere MSA meeting 08 - 10 June 2020. Online meeting with more than 85 participants; after updates of Head Office, Atmospheric Thematic Centre, Carbon Portal and Calibration Laboratories, sessions were mainly about recent technological advances like flask sampler capabilities and flask sampler communication, and progress in boundary layer height retrieval, followed by discussions about instrumental and data processing issues; as always, the last day was dedicated to a joint data review of all ICOS atmosphere data recorded since the last MSA in 2019.

Ecosystem MSA meeting May 4-5 May, 2020. Online meeting. After Corinna Rebmann stepped down as Ecosystem MSA chair, Janne Rinne was selected as new chair and Lukas Siebicke as new co-chair. The discussion on meeting included e.g. raw data policy, pre-ICOS data, new technical developments and updates on protocols.

Ocean MSA meeting 25 June 2020: Online meeting but well attended (nr of participants: 36) , many who would not normally travel for face to face. Main highlights and decisions were around the establishment of working groups on further support of the stations and especially the Fixed Ocean Stations.

8th ICOS-CH Annual Meeting 2021, 03.09.2021, virtual meeting. ICOS-CH consortium met for updates from ICOS Switzerland and ICOS RI. Highly interesting and up-to-date scientific talks both from the ICOS-CH Ecosystem and Atmosphere community were presented.

ICOS-Finland annual meeting 2020, 1.12.2020, 29 participants (organized in Zoom). All station PIs, technicians and other supporting staff giving updates on all stations and ongoing projects.

Annual Meeting of ICOS Germany was held on June 18 via WebEx with approximately 40 participants including station PIs, their teams, CAL directors and staff as well as delegates from the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the project management funding agency (PT-DLR). Contributions covered a wide range of scientific topics and progress reports from all domains. All committees presented their current status, recent developments, and planned initiatives.

The ICOS Norway annual meeting October 29th 2020 held virtually. All partners were represented. October 21st 2020: specialized seminar with ICOS Norway, the EU VERIFY project, and the Norwegian Environment Agency. October 28th 2020: ICOS Norway presented results from the national network at the **'Open meeting on greenhouse gas emissions'** in cooperation with the Norwegian Environment Agency <https://www.miljodirektoratet.no/aktuelt/arrangementer/2020/oktober-2020/apent-mote-om-klimagassutslipp/>.

Markus Leuenberger was co-organizer of 5th **VAO (Virtual Alpine Observatory) Symposium**, 04-06.02.2020, Bern, Switzerland

Staff working in national networks

note that Belgian technical staff also includes 0,45 FTE administrative staff%

Member/ Observer countries	Staff total (people)	Staff total (FTE)	Scientific staff (FTE in years)		Technical staff (FTE in years)	
			People	FTE	People	FTE
Belgium	30	17	11	6,92	19	11,23
Czech Rep.	33	11	22	4,7	11	6,5
Denmark	12	0	5		7	
Finland	19	7	4	1	15	6
France	90	30	35	12	55	18
Germany	71	25	37	10.5	34	14
Italy	69	15	41	9.5	28	5.5
Netherlands	9	4	6	2.5	3	1.5
Norway	22	7	14	4	8	3
Sweden	34	16	8	2.2	26	13.6
Switzerland	17	9	8	5	9	4.1
UK	2	1	2	0.87		
Total	408	141	193	48	215	66

Labelling

Status of the ICOS Station Labelling in November 2020 vs station numbers 2021

Member/ Observer countries	Stations total (2021)	Labelled station total	Number and type of stations														% labelled per country
			Ecosystem stations						Atmospheric stations				Ocean stations				
			C1	C1 labelled	C2	C2 labelled	Assoc.	Asso. labelled	C1	C1 labelled	C2	C2 labelled	C1	C1 labelled	C2	C2 labelled	
Belgium	11	7	1	1	4	3	2	1	0		1	1	2	1	1	0	64 %
Czech Rep.	4	1	1		1		1		1	1	0		0		0		25 %
Denmark	10	1	2	1	1	0	6	0	0		1	0	0		0		10 %
Finland	13	9	2	1	2	1	5	4	2	2	2	1	0		0		69 %
France	23	13	3	2	6	1	9	5	3	2	1	2	1	1	0		57 %
Germany	36	16	5	4	0		14	3	7	6	5	2	4	0	1	1	44 %
Italy	17	5	2	0	2	0	6	2	0		3	2	1	1	3		29 %
Netherlands	3	1	0		1		0		1		1	1	0		0		33 %
Norway	7	4	0		1		0		1	1	1	0	3	2	1	1	57 %
Spain	2	0	0		0		0		0		1	0	1	0	0		0 %
Sweden	11	7	0		6	4	0		3	3	0		2	0	0		64 %
Switzerland	2	2	1	1	0		0		1	1	0		0		0		100 %
UK	6	0	1	0	0		0		0		2	0	0		3	0	0 %
JRC	2	2	0		1	1	0		0		1	1	0		0		100 %
Total	147	68	18	10	25	10	43	15	19	16	19	10	14	5	9	2	46 %
			56 %		40 %		35 %		84 %		53 %		31 %		29 %		

Annex 1: Outreach activities

Belgium

- Mahesh Kumar Sha, Bavo Langerock, Corinne Vigouroux, Christian Hermans, Nicolas Kumps, Francis Scolas, Minqiang Zhou, Martine De Mazière, Jean-Marc Metzger, Valentin Duflot, Jean-Pierre Cammas, Carlos Augusto Bauer Aquino, Christiane Silvestrini de Morais, Luciana Vanni Gatti: Site Report: BIRA-IASB: Reunion Island stations & Porto Velho, Slides presentation at the Annual IRWG / TCCON meeting 2020, May 13 – 15, 2020, Virtual meeting.
- Hannelore Theetaert (VLIZ) participated in research campaign JC191 (US Florida to ES Canary Islands) performing UW pCO₂ and carbonate chemistry measurements using ICOS compliant equipment. Data from this activity were also submitted to SOCAT v2021. During this campaign she wrote several blogs:
 - The nightshift on JC191 (<https://projects.noc.ac.uk/class-project/blog/nightshift-jc191>)
 - Women in STEM day blog post (<https://projects.noc.ac.uk/class-project/blog/women-stem-day-blog-post>)
 - Making the most of a CLASS Fellowship: Underway surface seawater carbonate system measurements during cruise JC191 (<https://projects.noc.ac.uk/class-project/blog/making-most-class-fellowship-underway-surface-seawater-carbonate-system-measurements-during>)
- Hannelore Theetaert; Using a CLASS Fellowship to make measurements of the surface carbonate system; Ocean Challenge, Vol. 24, No.2, 2018 (pub. 2020)
- EGU 2020: Poster « Proofs of non-stomatal limitations of potato photosynthesis during drought by using eddy covariance data » Beauclaire, Q., Gourlez de la Motte, L., Heinesch, B., and Longdoz, B.
- Ose la science (asbl) : “Let's talk about climate: understand and act”. Meeting with the students of UNamur, presentation by Bernard Heinesch
- Study center of the agricultural techniques of Condroz and provincial Chamber of agriculture of Luxembourg : "Climate change and agriculture". Presentation by Bernard Heinesch.
- Writing of an article presenting the station of Lonze in the communal letter of Gembloux (edition of November 2020)
- Flemish newspaper De Standaard published two excellent longreads on ICOS and the 2018 extreme Summer drought study as part of a series about the impact of climate change on nature in Europe. The series is called ‘Het droge noorden’. The author visited and interviewed several stations of the ICOS network. The article featured interviews with PI's Caroline Vincke (Vielsalm) and Marilyn Roland (Maasmechelen) (in Flemish):
 - article on CO₂ compensation by trees: <https://www.icos-belgium.be/files/Kunnen%20we%20wel%20op%20bomen%20rekenen%20om%20de%20CO2-uitstoot%20te%20compens...%20-%20De%20Standaard.pdf>

- article on forests acting as potential CO₂ sources rather than sinks: <https://www.icos-belgium.be/files/Als%20een%20bos%20meer%20CO2%20uitstoot%20dan%20dat%20het%20er%20opslaat%20-%20De%20Standaard.pdf>
- ICOS Wallonia developed an Online visualization tool for the Lonze station during the year 2019 to provide an elaborate and easily accessible (on a website) graphical representation of the data acquired on stations. It will be used both for quality control measurements by the ICOS team, to inform the scientists using the site data and for internal communication within our institutions and external communication to a wider public. Update 2020 : finalization of the tool and implementation forecasted for the Vielsalm and Dorinne stations. The University of Antwerp is looking into the implementation of this tool for its stations as well.

Czech Republic

- Participation in the **Virtual ICOS Science Conference 2020**
 - Session 14, Vulnerability of the Carbon Cycle. (Poster presentation - *Analysis of floodplain forest sensitivity to drought*)
 - Session 15, Innovation and uncertainty in observation techniques. (Oral presentation - *Effect of summer drought on soil CO₂ efflux in four forest ecosystems*)
- Educational video on climate change's effects on the health of Czech ecosystems on YouTube: <https://www.youtube.com/watch?v=yRiXQwZMAg> (the video was highlighted among other by LI-COR company newsletter)

Denmark

A brochure of presenting ICOS/DK has been produced.

Finland

Interviews and public talks:

Annalea Lohila (9.1.2020) interviewed for national radio and TV, website news with title "*Pohjoisen selluhankkeita varjostavat isot ympäristöriskit – tutkimus varoittaa uusista ilmasto- ja vesistöpuu- ja nykyhakuilla*" (about the climate impact of peatland forestry) <https://areena.yle.fi/1-50410160>, <https://yle.fi/uutiset/3-11147406>

Annalea Lohila (31.1.2020), invited talk at Suopäivä 2020 with title "*Suot ja turvemaat IPCC:n erikois- ja arviointiraporttien valossa – uudet tutkimuskysymykset ja -tarpeet?*" (about peatlands in the IPCC reports)

Timo Vesala (30.3.2020), Utelias mieli -podcast with title "*Miksi hiilen ja veden avioliitto on elintärkeä luonnolle ja ilmastolle?*" (about the importance of coupling of carbon and water cycles) <https://www.helsinki.fi/fi/uutiset/kestava-kehitys/miksi-hiilen-ja-veden-avioliitto-on-elintarkea-luonnolle-ja-ilmastolle-kuuntele-utelias-mieli-podcast>

INAR podcast Veden kierto, 4 episodes (3.5.2020)

Part 1, Air: Dr. Laura Riuttanen, Hyytiälän SMEAR-asema ja tutkakenttä

Part 2, Wetland: Prof. Eeva-Stiina Tuittila, Lakkasuo

Part 3, Lake: Dr. Anne Ojala, Kuivajärvi, järvien, soiden ja metsien vuorovaikutus

Part 4, Forest: Assoc.prof. Mari Pihlatie, metsien tutkimus Hyytiälässä.

<https://soundcloud.com/inar-fin>; newspaper review <https://www.hs.fi/kulttuuri/art-2000006512806.html>

Annalea Lohila (9.9.2020) interview in newspaper article with title "*Tutkijoita karu viesti: Helteet ja kuivuus piinaavat yhä useammin ja heikentävät hiilinieluja ja satoja Euroopassa*" (about the impact of drought on land carbon sinks)

<https://www.maaseuduntulevaisuus.fi/maatalous/artikkeli-1.1186131>

Mika Korkiakoski (8.12.2020) press release by Finnish Meteorological institute with title "*Runsasravinteisten suometsien kasvihuonekaasupäästöt ovat merkittävästi pienempiä osittaishakkuun kuin avohakkuun jälkeen*" (about climate impact of peatland forest management) <https://www.ilmatieteenlaitos.fi/tiedote/46TfTWJlm79TpArMENaXTE>

Mika Korkiakoski (14.12.2020) press release/news article in ICOS Finland website with title "*Greenhouse gas emissions after partial harvesting are significantly lower than after clear-cutting in a nutrient-rich peatland forest*" <https://www.icos-finland.fi/node/27>

Public events:

#ICOScapes Photo Exhibition at the Natural History Museum (LUOMUS) 23 January – 15 March 2020. Opening event 22.1.2020 had 70 participants, altogether LUOMUS had 33500 visitors during the exhibition

Ilmastotunti – Climate hour event for young (ca. 14–18-year-olds) in Oodi Helsinki Central Library 28 February 2020 9:30–11:30. Ca. 170–180 participants. Program (in Finnish) included talks from experts at University of Helsinki and Finnish Meteorological institute: prof. Timo Vesala, associate prof. Annalea Lohila, Dr. Hannele Korhonen, associate prof. Leena Järvi, prof. Risto Makkonen and Dr. Hannakaisa Lindqvist. After the talks there was informal discussion with researchers from different backgrounds and career stages with the students.

Young Academy Finland: "Hiilinielut tutkimuksessa ja politiikassa" -virtual workshop 2.9.2020, 15 participants. (Carbon sinks in research and policy making)

<https://nuortentiedeakatemia.fi/2020/09/18/hiilinielut-tutkimuksessa-ja-ilmastopolitiikassa-kohti-tutkimuspohjaisia-maankayton-ratkaisuja/>

Meet the researcher -school visit at Munkkiniemi elementary school, April 2020 by Olli Peltola. <https://nuortentiedeakatemia.fi/tutkija-tavattavissa/>

Reports:

Aaltonen, H. (2020). *System and performance audit of carbon dioxide, methane and carbon monoxide measurement at the ICOS Class 1 atmospheric station Saclay, France, April–May 2019*. ICOS Atmosphere Thematic Centre Document TC-MOL-AU-RP-010-1.1.

Laurila, T., Rainne, J., Hatakka, J., Mäkelä, T., Tuovinen, J.-P., Kulmala, L. & Aurela, M. (2020). *Hiilidioksidin vuo, haihdunta ja ilmastomittaukset Lappilan metsitettävällä koekentällä. Raportti GRK:n Infrarakentamisen vähähiilinen toimintamalli hankkeen Tehtävä 3 edistymisestä*, Ilmatieteen laitos, Helsinki.

Peltola, O. (2020). Lukija/kommentaattori julkaisussa: Mäkinen-Rostedt, K., *Miten rakennetaan toimiva tieteen ja päätöksenteon suhde?* Nuorten Tiedeakatemia politiikkasuositus 1/2020, Nuorten Tiedeakatemia, Helsinki. https://nuortentiedeakatemia.fi/hallinta/wp-content/uploads/2020/08/FINAL_NuortenTiedeakatemia_PolicyBrief_v6.pdf

Germany

- Talks, interviews
 - Lüers K, Hohlfeld C (2020): Sorgenkind Wald. Effzett 3-20, S. 32-33.
 - <https://effzett.fz-juelich.de/3-20/sorgenkind-wald/>
 - https://fz-juelich.de/portal/DE/Presse/broschueren/effzett/_node.html
 - Interview (Mario Hoppema) for press release by ICOS Communication Office for labelling and Polarstern in the Arctic during MOSAiC expedition
 - <https://www.icos-cp.eu/event/953>
 - National TV (ZDF), Leschs Kosmos on 2. June 2020: How much green is needed for the blue planet?
 - <https://www.zdf.de/wissen/leschs-kosmos/wie-viel-gruen-braucht-der-blaue-planet-102.html>
 - Muller et al.: ICOS Drought Study, Highlight talk for scientific advisory council, Deutscher Wetterdienst, Offenbach, Germany, 19.02.2020
 - Kubistin et al.: ICOS-D Atmosphere Network, Interview at "Alle Wetter", HR3, Frankfurt, Germany, 31.08.2020
 - <https://www.ardmediathek.de/hr/video/alle-wetter/alle-wetter-vom-31-08-2020/hr-fernsehen/Y3lpZDovL2hyLW9ubGluZS8xMDgxODg/>
 - Press release DWD: Measurement and observation of greenhouse gases – Atmosphere measurement network of DWD fully operational (Messung und Überwachung von Treibhausgasen - Atmosphärenmessnetz des Deutschen Wetterdienstes vollständig in Betrieb, Helgoland / Hohenpeißenberg Offenbach, 12.08.2020)
 - https://www.dwd.de/DE/presse/pressemitteilungen/DE/2020/20200812_icos.html?nn=714786
 - Krüger, I., Sanders, T., Holzhausen, M., Schad, T., Schmitz, A. & Strich, S.: Am Puls des Waldes – Umweltwandel und seine Folgen – ausgewählte Ergebnisse des intensiven forstlichen Umweltmonitorings, Bundesministerium für Ernährung und Landwirtschaft, 2020, 51
 - <https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/puls-des-waldes.html>
 - TEREÑO Newsletter 1/2020: ICOS certifies TEREÑO sites
 - <https://www.tereno.net/joomla/index.php/resources/tereno-newsletter>
 - Talk to ministers of the state of Baden-Württemberg (Andreas Christen), 24.6.2020
 - Seelmann, K., Steinhoff, T. and Körtzinger, A. Level up ocean carbon observations: Successful implementation of a novel autonomous total alkalinity analyzer on a commercial Ship of Opportunity, EGU general assembly 2020.
 - <https://www.icos-cp.eu/sites/default/files/2021-03/ICOS%20OTC%20Newsletter%20March%202021.pdf>

Norway

In addition to the aforementioned meeting between ICOS Norway and the Norwegian Environment Agency, there was a specialized seminar in collaboration between ICOS Norway, the EU VERIFY project and the Norwegian Environment Agency Also in fall 2020 (October 21st). The meeting gave specialized staff in the ministries and agencies the opportunity to learn and discuss the state-of-the-art verification of greenhouse gases.

- In June 2020, NILU published a press release with input from Stephen Platt and Cathrine Lund Myhre on the impact of COVID-19 related lockdowns on atmospheric CO₂ levels: <https://www.nilu.com/2020/06/covid-19-lockdown-effect-on-global-carbon-dioxide-levels-a-needle-in-a-haystack/>, inspired by the ICOS press release 'Finding a hair in the swimming pool: The signal of changed fossil emissions in the atmosphere', by Werner Kutsch, Alex Vermeulen and Ute Karstens.
- In September 2020 we gave press releases detailing the construction of the new 75 m mast at Blårnes (e.g., <https://forskning.no/nilu-norsk-institutt-for-luftforskning/ny-atmosfaerisk-aera-for-norsk-luftmalestasjon/1745562>). A video of the upgrades also appeared in the local newspaper *Fædrelandsvennen*.
- In collaboration with *Klimastiftelsen* we prepared a Norwegian report on the global carbon budget, this can be found here: <https://klimastiftelsen.no/publikasjoner/utslipp-og-opptak-av-co2-2020/>

Finally, ICOS Norway maintains an active online/ social media presence:

- ICOS Norge: <https://no.icos-cp.eu/>
- OTC: <https://otc.icos-cp.eu>
- Twitter: *ICOS Ocean Thematic Centre* <https://twitter.com/otcco2>
- Facebook: ICOS Norway <https://www.facebook.com/ICOSNorway>

On our ICOS Norway Facebook page, 10 updates were posted on fieldwork, meetings, scientific use and outreach activities.

Switzerland

- Talks, interviews,

Buchmann, N.: Salt Lake City, UT (USA): Invited lecture at the Ecological Society of America Annual Meeting on „Resilience of forests and agroecosystems today and in the future” (virtual, 5.8.20)

Crotwell, A., H. Lee, M. Steinbacher (eds), 20th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Measurement Techniques (GGMT-2019), WMO/GAW report #255, World Meteorological Organisation, https://library.wmo.int/doc_num.php?explnum_id=10353, 2020

Ingenieur (2020) Gestresste Wälder, Wiesen und Äcker. *Ingenieur.de*. 09.09.2020, <https://www.ingenieur.de/technik/fachbereiche/umwelt/gestresste-waelder-wiesen-und-aecker/>

Läubli M (2020) Hitze schmälert die Klimaleistung der Wälder. *Tagesanzeiger*, 10.09.2020, <https://www.tagesanzeiger.ch/hitze-schmaelert-die-klimaleistung-der-waelder-968332933776>

National Geographic (2020) Sky-high science, National Geographic, vol. 237, no. 1, January, 2020.

ProClim (2020) Davoser Messstation für Treibhausgase offiziell zertifiziert. *ProClim News*. 27.02.2020, <https://naturwissenschaften.ch/organisations/proclim/current/news/123090-davoser-messstation-fuer-treibhausgase-offiziell-zertifiziert>

ProClim (2020) Davoser Messstation für Treibhausgase zertifiziert *ProClim Flash* 72. www.proclim.ch/flash/72

RTS L 1ère (Radio-Interview): Les forêts portent encore les stigmates de la sécheresse de l'été 2018, 17.07.2020, <https://www.rts.ch/info/suisse/11473533-les-forets-portent-encore-les-stigmates-de-la-secheresse-de-lete-2018.html>

Schuller J (2020) Studie: Trockenheit reduziert Produktivität von Wiesen und erhöht deren CO₂-Emissionen *BauernZeitung*, 07.09.2020, <https://www.bauernzeitung.ch/artikel/studie-trockenheit-reduziert-produktivitaet-von-wiesen-und-erhoeht-deren-co2-emissionen>

SchweizerBauer (2020) Schwieriger Sommer für Äcker und Wiesen *SchweizerBauer*. 07.09.2020, <https://www.schweizerbauer.ch/pflanzen/futterbau/schwieriger-sommer-fuer-aecker-und-wiesen/>

Vernimmen T (2020) Als een bos meer CO₂ uitstoot dan dat het er opslaat. *De Standaard*. 09.11.2020, https://www.standaard.be/cnt/dmf20201108_97902752

Würsten F (2020) A difficult year for forests, fields and meadows. *ETH News*. 07.09.2020, <https://ethz.ch/en/news-and-events/eth-news/news/2020/09/difficult-year-for-forests-fields-and-meadows-.html>

Würsten F (2020) Ein schwieriger Sommer für Wälder, Äcker und Wiesen. *ETH News*. 07.09.2020, <https://ethz.ch/de/news-und-veranstaltungen/eth-news/news/2020/09/ein-schwieriger-sommer-fuer-waelder-aecker-und-wiesen.html>

Zweifel R, Etzold S, Braun S, Köchli R, Hoch G, Eugster W, Walthert L (2020) TreeNet - am Puls der Bäume. *Wald und Holz*, vol. 3/20, pp 31-33

Zweifel R, Etzold S, Walthert L, Köchli R, Eugster W (2020) TreeNet – wann wachsen unsere Bäume? *Wald und Holz* vol. 5/20 pp 20-23.

Annex 2: ICOS Publications and references

Total of 1500 scientific articles are listed in the Carbon portal, 198 of which with year 2020.

<https://www.icos-cp.eu/science-and-impact/society-impact/references>

