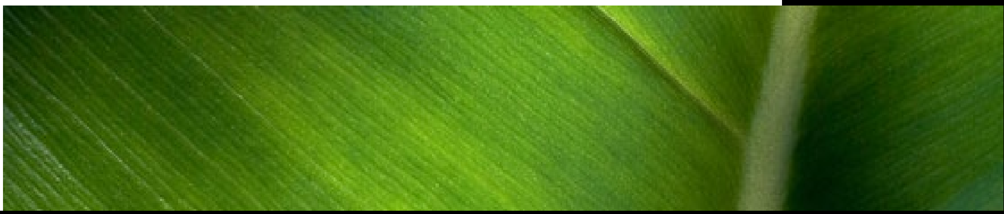
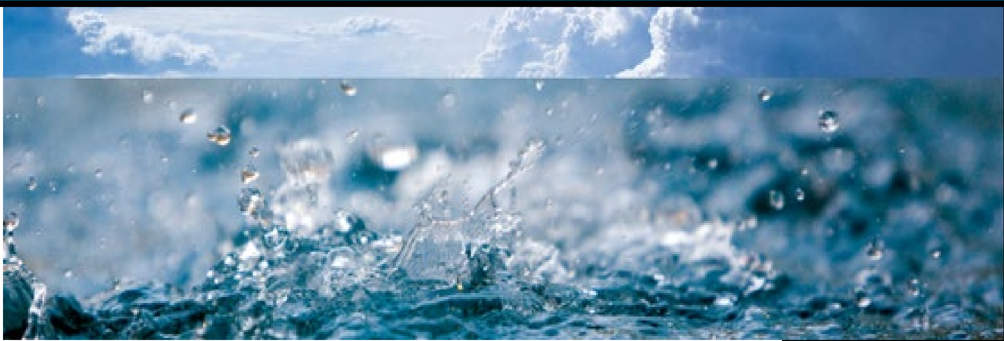
RINGO | Readiness of ICOS

Readiness of ICOS for Necessities of integrated Global Observations



Periodic Technical Report Part B



730944 RINGO Periodic Report 2 Technical Part B

Project Number: 730944
Project Acronym: RINGO
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Readiness of ICOS for Necessities of integrated Global Observations

Periodic Technical Report
Part B

Period covered by the report: 1/7/2018-31/12/2019

Periodic report: [2ND]

Contents

RINGO 2nd PERIODIC REPORT

1. INTRODUCTION AND EXECUTIVE SUMMARY

During the second reporting period of the RINGO project (1.7.2018 – 31.12.2019), the Integrated Carbon Observation System (ICOS) went through a crucial phase of its life cycle, and RINGO had a strong impact on this process by supporting specific steps. ICOS is a distributed European-wide research infrastructure producing high-precision data on greenhouse gas concentrations in the atmosphere, as well as on carbon fluxes between the atmosphere, the earth, and oceans.

ICOS became an ERIC in 2015, and in the ICOS ERIC statutes, the initial phase of the ERIC was defined as a five-year period (2015 – 2019). During this time, ICOS finalized its implementation phase and became stepwise operational with the first data of labelled stations becoming available for users through a well-defined data life cycle. Furthermore, it had to build up a reliable administrative structure for financial and operational management that ensures long-term sustainability, develop its communication and dissemination and its international cooperation.

However, accomplishing all these tasks have not been enough: ICOS had to organise a strategy-guided transition towards its second five-year period. RINGO had an important impact on all of these processes.

The overall objectives of the project are to enhance the readiness of ICOS to take current and upcoming challenges:

- **Scientific readiness.** To support the scientific use of data from the ICOS observational networks and their science-guided development. During the second reporting period, RINGO activities and deliverables had a large impact on the ICOS science. In particular, activities in WPs 1 (Deliverables D1.1 and 1.4) and 4 (Deliverable 4.2) supported ICOS-related science. The work on pre-ICOS data in Task 4.2 has been integrated into a larger initiative coordinated by ICOS that analysed the drought during the year 2018 compared to long-term data. In this context, a long-term pre-ICOS data set with the highest quality as prepared through RINGO has been very supportive.
- **Data readiness.** To improve data streams towards different user groups, adapting to the developing and dynamic (web) standards. The fulfillment of this objective is measurable by the activities performed in WPs 4 and 5. Particularly, the work on the ICOS data type-registry and unified meta-database in Task 4.1, which also increases the cross-domain interoperability of ICOS data and the deliverable D5.1 (GLODAP and SOCAT services) have been important steps forward here.
- **Geographical readiness.** To enhance ICOS membership and sustainability by supporting interested countries to build a national consortium, to promote ICOS towards the national stakeholders, to receive consultancy e.g., on possibilities to use EU structural fund to build the infrastructure for ICOS observations and also to receive training to improve the readiness of the scientists to work inside ICOS. These goals have been followed in WP 2. The most important result here is deliverable 2.1, which includes the ICOS Handbook and the fact that three of the supported countries (Spain, Poland, and Estonia) are close to becoming members of ICOS ERIC. Training events for potential ICOS members to be fully in line with ICOS technical and scientific standards were continued.
- **Political and administrative readiness**. To deepen the global cooperation of observational infrastructures and with that, the common societal impact. The fulfillment of this objective is measurable by the activities performed in WPs 1, 2, and 5. The most important result of the second reporting period is deliverable D1.1, which has integrated the entire strategic management of ICOS by providing a systematic management approach the includes strategy-derived activities as well as monitoring of performance and impact.
- **Technological readiness.** To further develop and standardize technologies for greenhouse gas observations necessary to foster new knowledge demands and to account for and contribute to technological advances. This objective is mainly supported by ongoing work in WP 3.

2. OVERVIEW OF THE WORK PACKAGES

Work Package 1

The main objectives of WP 1 are:

- **Analyse the impact of current ICOS monitoring towards possible mitigation strategies, including their cost-effectiveness**
- **Improve and supplement the current observation networks of ICOS by improving sampling and measurement strategies for (i) monitoring fossil fuel CO2 and verification of its emission inventories, (ii) supplementary and stable isotope tracers analysed on flask samples for CO2 and CH4 source apportionment and (iii) budgeting lateral carbon and GHGs fluxes via rivers, streams estuaries and ocean.**
- **Bridge current ground-based ICOS observations to satellite data via (i) TCCON vertical GHGs profiling (ii) space-based air-sea gas exchange parameters and (iii) using ICOS ground-truth information and LIDAR for validation of biomass parameters through space-based imaging.**

Task 1.1 provided a lot of support on the transition into the second five-year period. The impact analysis that had been conducted throughout the first reporting period became the base for the ICOS Strategy – a core document describing the future pathways of ICOS and itself base for the Five-year Action Plan (2020 – 2024) that was approved by the General Assembly in May 2019. Task 1.1 became finally also aligned with the ESFRI process to develop a monitoring system for ESFRI Landmark Research Infrastructures, thus, increased its impact even beyond ICOS itself. Deliverable D1.1, which has been submitted in the reporting period, comprises, therefore, more information than originally envisaged.

All experimental work of **Task 1.2** has been conducted as originally planned (MS 48), the results for the two-station approach to estimate fossil CO_2 emissions from a targeted area are currently evaluated. Forward runs for the $^{14}CO_2$ Observing System Simulation Experiment were finalized, and inversions to support designing a fossil CO_2 monitoring network in Central Europe are underway.

The flask sampling protocol developed in **Task 1.3** for all ICOS Class 1 stations has been finalized (MS 39 and D1.3); first stations are now collecting their samples with the accordingly programmed ICOS automatic flask sampler. The ICOS strategy to collect one-hour integrated flasks during low ambient CO2 variability situations for quality control of in situ measurements turned out to fulfill its purpose.

During two workshops, all partners contributing to **Task 1.4** discussed the ideal and minimum requirements of an aquatic transport and fluxes observation system to monitor land-ocean carbon fluxes, including carbon cycle processes in lakes and wetland ecosystems. A first draft summarising the results of these discussions was assembled (MS32, MS38, MS39); the final deliverable report D1.4 will be submitted in month 42.

The scientific-technical concept for the integration of European TCCON sites into ICOS (MS41 and D1.5), including estimates of resulting costs, has been developed in **Task 1.5.1** during two "*TCCON and ICOS data integration*" workshops. The corresponding deliverable report D1.5 has been submitted and was accepted. Also, in the framework of **Task 1.5.1,** the concept of AirCore measurements in future ICOS has been further developed as these observations provide complementary, vertical profile information to the ICOS Atmosphere domain as well as calibration of TCCON retrievals to the WMO scales. Under **Task 1.5.2**, MS 42 has been completed by extending, verifying, and publishing the Version 3 update to the FluxEngine open-source (BY-NC) air-sea flux software toolbox, which is publicly available. This update to the toolbox is accompanied by a journal publication, and interactive tutorials are packaged with the toolbox that use iPython. Deliverable report D1.6 has been submitted and was accepted. Under **Task 1.5.3**, a field protocol for forest ground Lidar (TLS) measurements at ICOS sites was developed (M 40) and tested at six ICOS sites (M 50). A conference on "*TLS in forest ecology - expanding the horizon*" was organised by and conducted in Ghent in May 2019.

Work Package 2 Enhancing ICOS membership and sustainability

The main objectives of WP2 are:

- **To foster capacity-building in Research Infrastructure management, related scientific knowledge and Research Infrastructure human capital development in relevant regions.**
- **To enlarge the ICOS membership to increase the geographical coverage of the ICOS observations.**
- **To train new ICOS members to be fully in line with ICOS technical and scientific standards.**

All the above-mentioned objectives have been successfully addressed. It can be briefly summarised, based on the collaboration with all the WP2 members, that various capacity-building activities were done, near future enlargement of ICOS have been successfully negotiated and prepared for three new countries (Spain, Poland, and Estonia) and training activities (including training materials) have been prepared.
The work carried out in WP2 during the second reporting period (M19–M36) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

Work Package 3 Technical developments

The main objective of WP3 is to

- **explore the technological necessities to enable the scientific concepts developed in WP 1.**
- **It comprises technical pilot studies or workshop-based conceptual studies that will provide clear guidance for further technical innovations within ICOS.**

The short summary of the main achievements are: i) although delayed from the original schedule, considerable progress has been made in developing and testing the autonomous systems to measure the partial pressure of CO_2 in ocean surface waters on commercial carrier ships; ii) Trainou campaign (France) was organized for extensive profile measurements of CO_2, CH_4, CO, COS and N_2O concentrations; iii) a self-contained, low power and volume instrument for accurate measurement of air and surface water pCO_2 was built and lab- and field-tested to be suitable for integration into a waveglider; iv) all necessary information and results for the state-of-art non-CO_2 eddy-covariance measurements are available and the writing of a report “Protocol on non-CO_2 eddy-covariance measurements, QA/QC, data processing and gap-filling” is in progress; v) the analysis of the temporal and spatial variations in CO_2 fluxes was carried out for gross primary productivity (GPP) based on data from almost 150 flux towers and a quantitative attribution to the increasing CO_2 concentration was achieved.

The detailed description of the work carried out in WP3 during the second reporting period (M18-M36) is reported in the next section of this document, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

Work Package 4 Improving Data

The main objective of WP4 is to

- **increase the interoperability of ICOS data through a meta-data type registry.**
- **Improving and making legacy (pre-ICOS) data available at the best possible level of quality, including uncertainties.**

Task 4.1: Metadata is a core requirement for making data FAIR. Clear metadata management has a huge impact on the functioning of distributed research infrastructures. ICOS has always been a forerunner in open data management and in developing respective connections to and data services for the European Open Science Cloud. It has become a benchmark for other distributed environmental research infrastructures. Within the RINGO project, the data readiness of ICOS is further developed. During the second reporting period, the agreement has been reached on the mechanisms for live exchange of metadata within ICOS with regards to persons, roles, instruments, and stations between the ICOS Thematic Centers, Head Office, and Carbon Portal and the responsibilities for the updates. All TCs have started to implement part or all of the dynamic metadata exchange, and the Carbon Portal at LU/ERIC has set up the system to ingest and transfer the metadata into the central ICOS versioned RDF metadata store. The person and role information has been integrated with the dynamic data object landing pages to always show the up to date attribution information in the citation string for all ICOS observation data from Level 0 to Level 2. Within RINGO, we have now laid a firm basis for an improved and unified multi-domain ICOS metadata system.

All partners have worked on the provision of the improved legacy datasets for atmospheric CO_2 concentrations and ecosystem CO_2 fluxes in **Task 4.2**. The work has been integrated into a larger initiative coordinated by ICOS that analysed the drought during the year 2018 compared to long-term data. Thus, the delivery of the datasets by the TCs has been postponed by them to just after this reporting period.

Work Package 5 Towards a Global Carbon and GHG observation system

The main objective of WP5 are:

- **Further developing a concept for a global carbon and GHG information system with partner organisations.**
- **Developing ICOS OTC towards the European pillar of GLODAP and SOCAt**
- **Developing ICOS ETC towards the European pillar of FLUXNET**
- **Developing ICOS ATC towards the European pillar of WDCGG**

While the concept of the global network of cooperation with key actors has been discussed, coming into an MoU (if this is deemed to be the proper way forward with all the actors) still requires further discussions which is expected to go even beyond the duration of the project. However, significant steps forward have been achieved. The Carbon Portal of ICOS ERIC has been active in participating and coordinating actions. The Director of Carbon Portal has participated in several WMO GAW and IG3IS meetings, and the Carbon Portal and ULUND hosted a IG3IS/Transcom meeting in Lund 2018 attended by nearly 100 scientists and contributed to the follow-up meeting in Paris 2019. Also, discussions have started with the World Data Center for Greenhouse Gases on the automatic ICOS data flow into the global database.

Significant advances have also been made with the ICOS Thematic Centers becoming operational pillars for global networks. Currently, data from ocean domain, SOCAT, and GLODAP, is handled at one point by UiB, making UiB and ICOS OTC a global key player and elementary part of these data products. NERCUEA has supported OTC in regards to SOCAT, as well as coordinated the public release of SOCATv2019. Also, the respective websites for GLODAP (www.glodap.info) and SOCAT (www.socat.info) were established, updated, are being maintained and hosted by ICOS OTC partner UiB. UNITUS made progress with the ecosystem domain by releasing a common processing tool applied by large networks, by formalizing agreements with AmeriFlux and NEON about harmonization of standards, licence and metadata, and by supporting the open access release of data from over 200 stations. UVSQ progressed within the atmosphere domain by contributing to IG3IS with CO2-low-cost-sensor tests in and around cities, by gathering the most extensive CO2 dataset over Europe, and by advancing measurement techniques in international meetings.

Work Package 6 Management

Work Package 6 is responsible for the day-to-day running of the project. The main objectives of WP6 are:
• Concentrating on day-to-day management activities of the project
• Being responsible for project internal coordination structure, financial and administrative management, governance, project reporting coordination and risk management

During the second reporting period, WP6 has produced the final versions of the project's Risk Management Plan, Dissemination Strategy, and Data Management Plan. The Annual Project Meeting was organised in March 2019 in Southampton, including the RINGO General Assembly. The coordination team has also organised bi-monthly Executive Board meetings to check the project's progress, as well as individual teleconferences with each Task Leader to provide a platform for a more detailed discussion about practical matters.

IMPACT

According to the INFRADEV call to individually support research infrastructures, the RINGO project has been responding to, “Support will be provided to activities aimed at ensuring long-term sustainability, including enlargement of the membership, European coverage, international cooperation… and increase reliability and create trust, the definition of service level agreements and business/funding plan, outreach, and technology transfer activities.” The proposal has broken this down to several lines of impact of the RINGO project on ICOS, which are revisited in the following sections.

Impact on the internal development of ICOS

In particular, during the second reporting phase, the RINGO unfolded its full impact on the internal development and the general management of ICOS RI. The impact study conducted within the RINGO framework provided an excellent base for the formulation of the ICOS Strategy. Once the strategy was agreed on, the further work within Task 1.1 of RINGO was to support **the final formulation of the management plan** of ICOS RI by developing strategy-derived KPIs and KIIs to be used in the upcoming evaluation or ICOS.

Figure 1: Stepwise improvement of the ICOS RI governance during the past two years. The red parts symbolise strong impact by the RINGO project.

Further impact on the internal development of ICOS RI arose from D1.3, where a **flask sampling protocol** was developed based on historical time series and footprint modelling. This protocol improves the ability of the ICOS station network to detect fossil fuel emissions severely and has a strong impact on the resource efficiency of the sampling.

Impact on membership and sustainability of ICOS ERIC

The project aims to enlarge the network of potential new members joining to ICOS RI by involving interested countries in the activities of the WP2, thus enabling the transfer of knowledge, contact, and cooperation of the existing members and new members aspiring to join. The impact of WP2 on ICOS has become visible in the fact that **three new countries** (Spain, Poland, and Estonia) are currently preparing for joining ICOS ERIC as members. The basic training of the national consortia for the successful negotiations and preparations has been conducted with RINGO support.

Impact on the further technical development of GHG measurements

Domain- and scale-overarching bundling of existing expertise on the GHG measurements technologies and methods will create valuable synergies and foster the development and standardization of new measurement methodologies, applications, and parameters measured. The ongoing work in Task 3.4 will have a global impact on the measurements of CH4and N2O fluxes.

Scientific impact

The scientific-technical concept for the **integration of European TCCON sites into ICOS** (Deliverable D1.5) suggests the addition of high-quality data streams from novel platforms. If successfully implemented, this concept will stimulate the development of new scientific approaches. Further scientific impact results the **accurate calculation of air-sea gas fluxes** provided by Deliverable D1.4.

The flux of climate critical gases, such as carbon dioxide (CO2), between the ocean and the atmosphere, is a fundamental component of our climate and the biogeochemical development of the oceans. The ongoing work on integrating the **ICOS metadata** (Task 4.1) will improve the FAIRness of the ICOS data life cycle. This will improve the scientific work with ICOS data.

Impact on global in-situ observation system on GHG

The involvement of ICOS in a global observation and information system on carbon and GHG is a strategic goal for ICOS. The developments for **GLODAP and SOCAT** (Deliverable D5.2) made ICOS RI visible to the international scientific marine biogeochemistry and marine data management community. There is no doubt that the data management infrastructure of ICOS OTC is a global and the main European key player for these and there is no doubt that the objective of the deliverable has been achieved to make ICOS the European pillar of GLODAP and SOCAT by providing core services for both data networks.

Impact on industry and SME in technical development

There is no direct involvement of industry in the technical developments of this proposal. The reason for this is the high performance of ICOS in the specification of its stations and sensors that have been achieved during the past decade of developing this RI.

Societal impact

The main indicator for the societal impact of ICOS is the degree of knowledge transfer to the main policy forums such as IPCC, GCP, and UNFCCC. ICOS became Intergovernmental Observer Organisation at UNFCCC in December 2019, which enables the transfer of scientific and technical advancements by participating in meetings and events organised by the UNFCCC, especially in the Research Dialogue by the Subsidiary Body for Scientific and Technological Advice (SBSTA). Part of the societal impact is manifested by ICOS contributions to existing value chains that reach the wider public, such as the services provided by Copernicus and the WMO. Progress made in RINGO to make ICOS the European pillar of relevant global networks and the developments of global datasets, such as GLODAP and SOCAT, improve the accuracy and quality of the services provided by the established actors and thus contribute to the societal impact of ICOS.

3. Explanation of the work carried out by the beneficiaries and Overview of the progress

List of Deliverables delivered in this reporting period:

WP No	Del No	Title	Lead Beneficiary
WP1	D1	Strategy document on increasing impact of ICOS, including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs.	ICOS ERIC
WP1	D3	An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling.	UHEI
WP1	D5	Scientific-technical concept for the integration of European TCCON sites into ICOS and resulting costs.	UVSQ
WP1	D6	Ocean-atmosphere flux NRT data calculation routine, including satellite data streams on surface temperature, skin effects, wave state, and wind speeds.	NERC

WP2	D8	Report on enhancing membership strategy for ICOS ERIC, including the online Handbook for Stakeholders.	ICOS ERIC
WP2	D9	Concept document on collaboration with countries and stations outside the European Union	ICOS ERIC
WP5	D23	GLODAP and SOCAT services fully implemented at OTC.	UiB
WP6	D37	Final Dissemination Strategy	ICOS ERIC
WP6	D38	Final Data Management Plan	ICOS ERIC
WP6	D39	Final Risk Management Plan	ICOS ERIC

List of Milestones achieved during this reporting period

Milestone number	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS30	Raw data and ancillary data from 9 ecosystem stations compiled for re-processing	WP3	3 - UNITUS	20	Raw data and ancillary data from 9 ecosystem stations compiled for re-processing
MS31	An ICOS flask sampling protocol based on historical time series and high resolution footprint modelling.	WP1	5 - UHEI	24	An ICOS flask sampling protocol based on historical time series and high resolution footprint modelling.
MS32	Conwy Catchment workshop held	WP1	8 - NERC	24	Conwy Catchment workshop held
MS33	First summer school providing scientific training for new countries held	WP2	6 - UVGZ	24	First summer school providing scientific training for new countries held
MS34	Report on enhancing membership strategy for ICOS ERIC finalized	WP2	6 - UVGZ	24	Report on enhancing membership strategy for ICOS ERIC finalized
MS37	Global network of cooperation finalized	WP5	1 - ICOS ERIC	24	Global network of cooperation finalized
MS38	Hyytiälä Forestry Field Station workshop held	WP1	9 - UHEL	30	Hyytiälä Forestry Field Station workshop held
MS40	Forest ground Lidar measurements completed	WP1	12 - UANTWERPEN	30	Forest ground Lidar measurements completed

Milestone number	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS41	Scientific-technical concept for the integration of European TCCON sites into ICOS	WP1	4 - UVSQ	30	Scientific-technical concept for the integration of European TCCON sites into ICOS
MS42	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational	WP1	8 - NERC	30	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational
MS43	Virtual training platform completed, all training material uploaded	WP2	6 - UVGZ	30	Virtual training platform completed, all training material uploaded
MS45	Ambient CO2 time series for the selected ten atmospheric measurement stations published at carbon portal	WP4	1 - ICOS ERIC	30	Ambient CO2 time series for the selected ten atmospheric measurement stations published at carbon portal
MS47	GLODAP and SOCAT services fully implemented at OTC	WP5	2 - UiB	30	GLODAP and SOCAT services fully implemented at OTC
MS48	Samples of ffCO2 emissions from all stations analysed	WP1	5 - UHEI	34	Samples of ffCO2 emissions from all stations analysed
MS49	Periodic Report 2 including request for a second interim payment	WP6	1 - ICOS ERIC	34	Periodic Report 2 including a request for a second interim payment
MS50	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available	WP1	12 - UANTWERPEN	36	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available
MS51	Second summer school providing scientific training for new countries held	WP2	6 - UVGZ	36	Second summer school providing scientific training for new countries held
MS52	High accuracy in- situ vertical profile measurements completed	WP3	7 - RUG	36	High accuracy in-situ vertical profile measurements completed
MS53	Technological Handbook and Assessment Report on CO2-ASV	WP3	23 - GEOMAR	36	Technological Handbook and Assessment Report on CO2- ASV
MS55	Final Dissemination Strategy	WP6	1 - ICOS ERIC	36	Final Dissemination Strategy
MS56	Final Data Management Plan	WP6	1 - ICOS ERIC	36	Final Data Management Plan
MS57	Final Risk Management Plan	WP6	1 - ICOS ERIC	36	Final Risk Management Plan

4. Explanation of the work carried out per Work Package

Work Package 1: Increasing the impact of ICOS

Summary

WP1 has successfully conducted all its envisaged tasks, thus reaching milestones (MS) and submitting deliverable reports in due time with only a few exceptions. Under Task 1.1, 1-ICOS-ERIC analyzed the requirements and has put together a strategy document on how to increase the impact of ICOS and make general recommendations to ESFRI for comprehensive impact analyses for distributed environmental Research Infrastructures (RIs).

A corresponding deliverable report (D1.1) has been submitted in the reporting period. All experimental work of Task 1.2 has been conducted as originally planned (MS 48), the results for the two-station approach to estimate fossil CO2 emissions from a targeted area are currently evaluated. Forward runs for the 14CO2 Observing System Simulation Experiment were finalized, and inversions to support designing a fossil CO2 monitoring network in Central Europe are under way. The flask sampling protocol developed in Task 1.3 for all ICOS Class 1 stations has been finalized (MS 39 and D1.3); first stations are now collecting their samples with the accordingly programmed ICOS automatic flask sampler. The ICOS strategy to collect one-hour integrated flasks during low ambient CO2 variability situations for quality control of in situ measurements turned out to fulfill its purpose.
During two workshops, all partners contributing to Task 1.4 discussed the ideal and minimum requirements of an aquatic transport and fluxes observation system to monitor land-ocean carbon fluxes, including carbon cycle processes in lakes and wetland ecosystems. A first draft summarising the results of these discussions was assembled (MS32, MS38, MS39); D1.4 will be delivered in May 2020 (month 41). The scientific-technical concept for the integration of European TCCON sites into ICOS (MS41 and D1.5), including estimates of resulting costs, has been developed in Task 1.5.1 during two “TCCON and ICOS data integration” workshops. The corresponding deliverable report D1.5 has been submitted and was accepted. Also, in the framework of Task 1.5.1, 7-RUG developed the concept of AirCore in future ICOS as these observations provide complementary, vertical profile information to the ICOS Atmosphere domain as well as calibration of TCCON retrievals to the WMO scales.
Under Task 1.5.2, 8-NERCUoE completed MS 42 by extending, verifying, and publishing the Version 3 update to the FluxEngine open-source (BY-NC) air-sea flux software toolbox, which is publicly available. This update to the toolbox is accompanied by a journal publication, and interactive tutorials are packaged with the toolbox that use iPython. Deliverable report D1.6 has been submitted and was accepted. Under Task 1.5.3, a field protocol for forest ground Lidar (TLS) measurements at ICOS sites was developed (M 40) and tested at six ICOS sites (M 50). A conference on “TLS in forest ecology - expanding the horizon” was organised by 12-UAnt and conducted in Ghent in May 2019.

List of deliverables due to be completed within this task within this reporting period:
D1.1 (carried over from PR1) Strategy document on increasing the impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs
D1.3 An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling. (M24)
D1.4 Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system including the possible role of ICOS RI and resulting costs to be presented to EC, ESFRI, and ICOS General Assembly. This document will also include possible cooperation with DANUBIUS RI. (M30)
D1.5 Scientific-technical Concept for the integration of European TCCON sites into ICOS and resulting costs. (M30)
D1.6 Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state, and wind speeds. [30]
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS48	Samples of ffCO2 emissions from all stations analysed	WP1	5-UHEI	34	Samples of ffCO2 emissions from all stations analysed
MS31	An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling.	WP1	5 UHEI	24	An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling
MS32	Conwy Catchment workshop held	WP1	8 NERC	24	Conwy Catchment workshop held
MS38	Hyytiälä Forestry Field Station workshop held	WP1	9 - UHEL	30	Hyytiälä Forestry Field Station workshop held
MS39	Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system	WP1	8 - NERC	30	Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system
MS40	Forest ground Lidar measurements completed	WP1	12 - UANTWERPEN	30	Forest ground Lidar measurements completed
MS41	Scientific-technical concept for the integration of European TCCON sites into ICOS	WP1	4 - UVSQ	30	Scientific-technical concept for the integration of European TCCON sites into ICOS
MS42	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational	WP1	8 - NERC	30	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational
MS48	Samples of ffCO2 emissions from all stations analysed	WP1	5 - UHEI	34	Samples of ffCO2 emissions from all stations analysed
MS50	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available	WP1	12 - UANTWERPEN	36	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available

Contributions per task:

Task 1.1: Analysis of requirements and possible impact of developing ICOS as European pillar of a global in-situ system resulting from COP 21

Task leader: ICOS ERIC (6)

Partner: (1) ICOS ERIC
Description of work carried out in T1.1 by beneficiary
During the reporting period, the development of a strategic approach on providing a vision of ICOS for the next decade and on increasing performance and impact related to multiple expectations was continued and completed by submitting Deliverable D1.1. The work has been based on ICOS Impact Assessment Report that had been completed in the first reporting period and comprised support for developing the ICOS Strategy and the Five-year Action Plan (2020 - 2024). Based on these experiences, a strategic approach for the description of ICOS core processes and related KPIs and KIIs has been developed, resulting in a matrix combining five strategic areas and five key activities of ICOS and, thus, defining 25 potential processes that can be systematically described, monitored and evaluated.

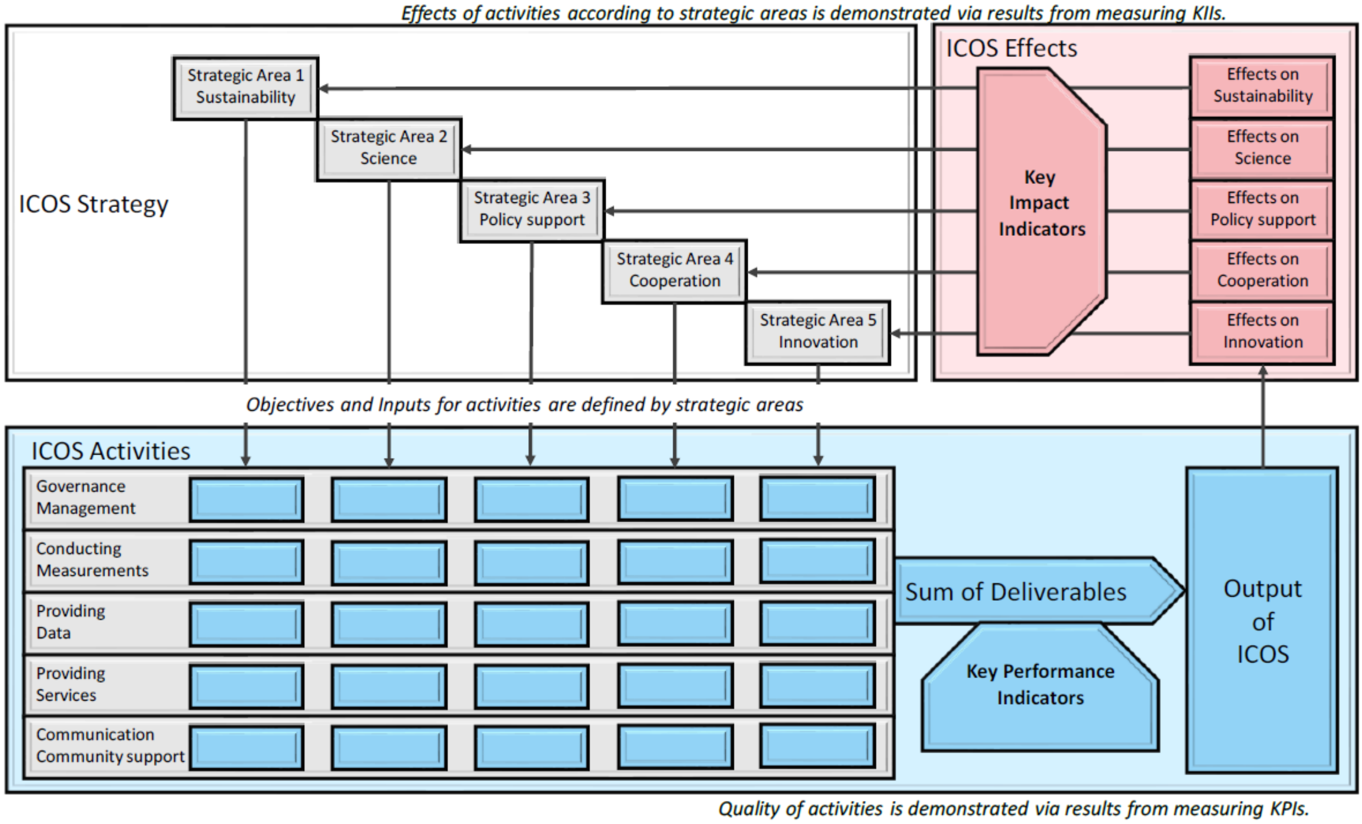

Figure. 2: Two-level conceptual framework distinguishing between Key Performance Indicators and Key Impact Indicators.

The five strategic areas and five key activities of ICOS form a matrix of 25 potential processes, each with deliverables that together define the output of ICOS (more detailed description in Chapter 2.3). Key performance indicators ideally measure the output of ICOS along these deliverables. The output has effects that can be related to the strategic areas and form in summary, the impact of ICOS. Thus, the Key Impact Indicators should be related to the ICOS Strategy and provide a measure on how well the strategic goals of ICOS have been achieved.

Significant results:

Deliverable D1.1, 'Strategy document on increasing the impact of ICOS, including a recommendation to ESFRI for comprehensive impact analyses for distributed environmental Research Infrastructures (RIs)' has been finalised and submitted. It describes the types of societal impact and the ways of measuring it for ICOS as an example for a distributed environmental European Research Infrastructure. It identifies ways to monitor and increase impact via Key Impact Indicators (KIIs), identified in the 'ICOS Impact Assessment' Study, conducted in 2018, and annexed to the document. D1.1, furthermore, summarizes a holistic process of self-reflection that was run over a period of more than two years, where all bodies of this distributed research infrastructure contributed to. The process was well-timed towards the end of the first five-year period of ICOS ERIC (2015 – 2019) and the transition from implementation to operation. In parallel to the Impact Assessment Study and party inspired by it, ICOS developed a Strategy that will guide its development through the upcoming decade e.g. by setting the goals for a five-year action plan 2020 – 2024 that has been approved by the General Assembly in May 2019.

Furthermore, this document aims to demonstrate how defining the societal expectations for an RI that operates in specific fields is a unique process. To facilitate the recognising of the link between societal impact and the work conducted in environmental RIs, this document introduces a strategical structure for managing and planning the RIs operations by presenting a two-level framework that takes into account both the RI's performance and impact – both of which are crucial in the wider pan-European Research Infrastructure landscape. Thus, the starting point for a comprehensive approach is based on strategic focus areas and connects these to core activities. This results in a hierarchical system of processes and tasks connected to the Strategy and measurable with Key Performance Indicators (KPIs). The connection of both, the KPIs and the Key Impact Indicators (KIIs) to the strategic focus

areas elegantly relates them to each other. As the consequence of a future assessment, it might, therefore, be possible to work on better performance of ICOS RI or to modify the activities when the impact is not as expected.
Lastly, this document draws from the ICOS experiences accumulated in the course of the last two years, a set of recommendations for designing performance and impact analyses for environmental RIs, and discusses the problematics in attempting to use a common set of indicators for all pan-European RIs.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The work in Task 1.1.has been extended during the course of the project in order to harmonise it with the ESFRI process of developing a monitoring concept for Landmark Research Infrastructures. There has been an intense exchange with the respective ESFRI working group. In order to continue this exchange, it is foreseen that a few remaining resources (< 1 PM) will be allocated to Task 1.1 even after the submission of the deliverable D1.1.

Task 1.2: Developing ICOS RI readiness to provide information on fossil fuel emissions

Task leader: UHEI (8); Participants: ULUND (3), UVSQ (11), RUG (7), RUGWU (7)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS48	Samples of ffCO2 emissions from all stations analysed	WP1	5-UHEI	34	Samples of ffCO2 emissions from all stations analysed

Partner: 5-UHEI

Description of work carried out in T1.2 by beneficiary

Beneficiary (5) UHEI contributed to Milestone MS48 by analysing the radiocarbon content in atmospheric CO2 in about 100 samples from the Freinsheim-Heidelberg station pair and 36 samples from the Gonesse-Sacley station pair. Further samples from Paris are in the processing chain: three samples are processed for AMS analysis, and 12 samples are at the FCL in Jena and await 14CO2 analysis thereafter.

Significant results:

Besides their use as input for modelling, the 14CO2 measurements at the Freinsheim-Heidelberg station pair also serve as data basis to discuss the following scientific questions:

a) What is the advantage of a local background station compared to a regional background station?

b) Can the difference in total CO2 concentration between the stations be used as a proxy for the difference in fossil fuel CO2?

Both of these questions have been addressed in the master thesis of Christoph Rieß [2019], and a publication is currently in preparation.

Concerning the difference between local and regional background, we can conclude that the local background, with few exceptions, always provides higher fossil CO2 concentrations. During the winter months, estimates of fossil CO2 concentrations vary between 20 and 40% depending on the choice for the background station. During summer, however, the different background stations even lead to different signs of the fossil fuel contribution. While the ffCO2 calculation with respect to the regional background leads to negative fossil fuel concentrations in Heidelberg, the usage of the local background still results in positive ffCO2 contributions. Negative ffCO2 concentrations are not physical and can only occur as an artefact of the ffCO2 calculation if the 14C depletion at the background station is larger than at the downwind station. Possible reasons are either nuclear contamination of the downwind station or fossil contamination of the background station; both possibilities are currently investigated. Our preliminary conclusion regarding the usage of the different background stations is that during the winter months, the use of the regional background is possible at the expense of additional uncertainty and loss of space allocation. The great advantage of using the regional background is the possibility to double the number of samples at the downwind station. The OSSE will hopefully show which approach will best reduce the overall uncertainty. In the summer months, the use of the regional background seems not applicable, at least not for the Freinsheim-Heidelberg station pair, which implicitly selects only westerly wind situations.

Figure 3 related the measured ffCO2 between Freinsheim and Heidelberg to the simultaneously measured total CO2 difference. The different seasons are shown in different colours and the 1:1 relationship is given by the dashed black line. During the winter month (DJF=blue) the total CO2 difference is dominated by the ffCO2 contribution, although a small non-fossil CO2 offset remains. The regression yields a slope for the winter month of 0.68ppm/ppm with an uncertainty of 15% and an R2 of 0.93. Thus, during winter, the total-CO2 proxy seems to be more robust compared to traditionally evaluated proxies like CO. In the summer months, biosphere exchange fluxes become dominate and rule out the ffCO2 contribution, preventing the use of total CO2 as ffCO2 proxy.

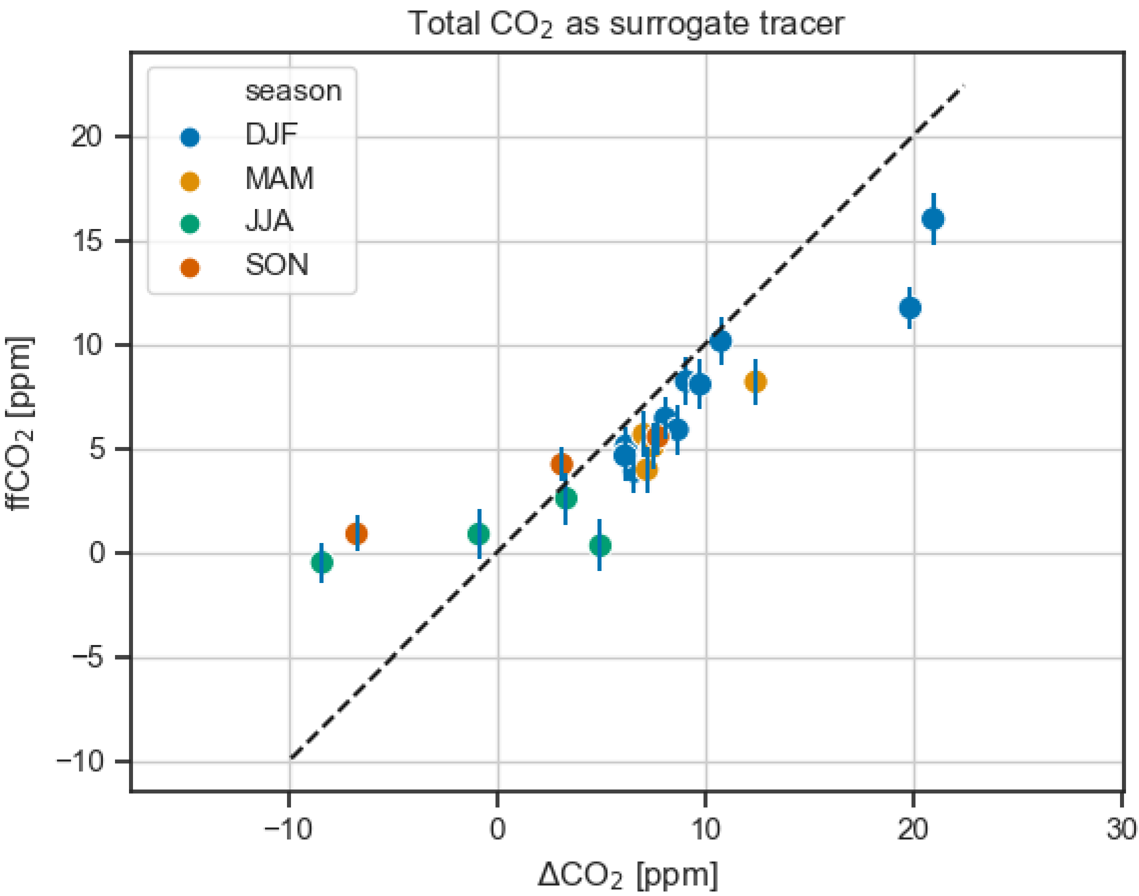

Figure 3: Relationship between the difference in total CO2 and fossil CO2 for the pair of stations: Freinsheim-Heidelberg. The different colours indicate different seasons. The dashed line is the 1:1 line.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The analysis of 14C samples from Paris is lagging behind the DoA. This is caused the delayed finalisation of the flask sampler and by technical problems with the stations in Saclay and Gonesse. We will continue to analyse the samples from Paris.

D1.1 was finalised during RP2 instead of RP1, as indicated in the DoA. Due to the ongoing simultaneous processes related to this topic in ESFRI, a decision was made to align the work in this deliverable with those discussions.

Partner: 10-ULUND

Description of work carried out in T1.2 by beneficiary:

Beneficiary (10) ULUND contributed by providing support for the selection of potential station pairs for monitoring ffCO2 from cities.

Significant results:

ICOS Carbon Portal at Lund University provided support for conducting model simulations using the STILT footprint tool installed at ICOS CP and for the collaborative analysis of the model simulations via a virtual research environment based on Jupyter notebooks. Based on the simulations of atmospheric CO2 concentration and sensitivity footprints, a set of potential station pairs was selected to be used in the Observation System Simulation Experiment.

Partner: 4-UVSQ
Description of work carried out in T1.2 by beneficiary:
UVSQ is in charge of the measurement program in Paris. We maintain continuous measurements of CO2, CH4, and CO concentrations at Saclay (20 km South/West of Paris), and Gonesse (20 km North/East of Paris). The two stations are located in the axis of the prevailing winds, with the station of Saclay generally upwind of Paris, with lower CO2, CO, and CH4 concentrations (Figure 4). As shown in Figure 4, we observe frequent CH4 spikes at Gonesse due to a waste centre located a few kilometres north. This installation does not perturb significantly CO2 and CO time series. A calibration correction will have to be applied to GNS data in July 2019.
The flask samplers developed by UHEI were installed at Saclay and Gonesse in April 2019 (Figure 5). In the first step, we have been using 2 liters flasks which were available at LSCE. Only from January 2020 on, we were using 3 liters flasks, which enable more precise measurements of 14CO2. Since the two stations are well located in the axis of the prevailing winds, we frequently have air masses passing over both stations, with Paris downtown in the middle, within few hours. With the help of UHEI, we are now using forecast trajectories from DWD (Figure 6) to prepare the sampling at both sites taking into account the expected delay between the two sites. The day after the sampling, we check the CO2 and CO in-situ measurements in order to decide if the signal is worth the radiocarbon analysis or not. So far we have sampled 19 pairs of samples. Two pairs have been contaminated due to leakages in the flasks. The measurements are still under evaluation, but the typical fossil fuel signal due to the emissions between Gonesse and Sacaly is on the order of 3 to 5 ppm.

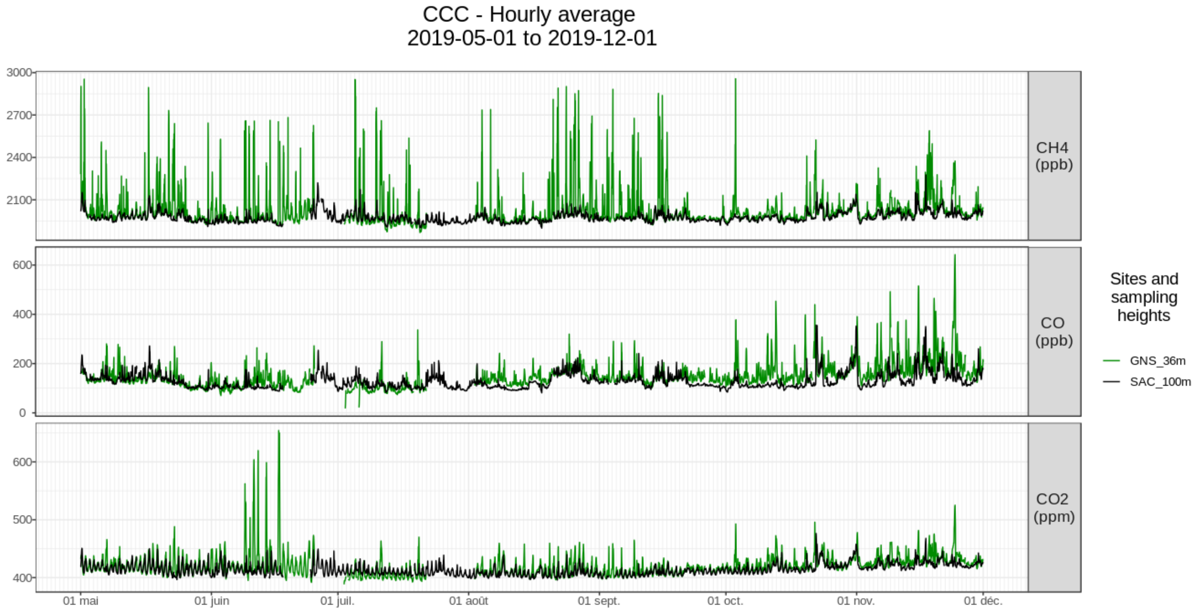

Figure 4: Time series of CO2, CO, and CH4 at Saclay, and Gonesse in 2019

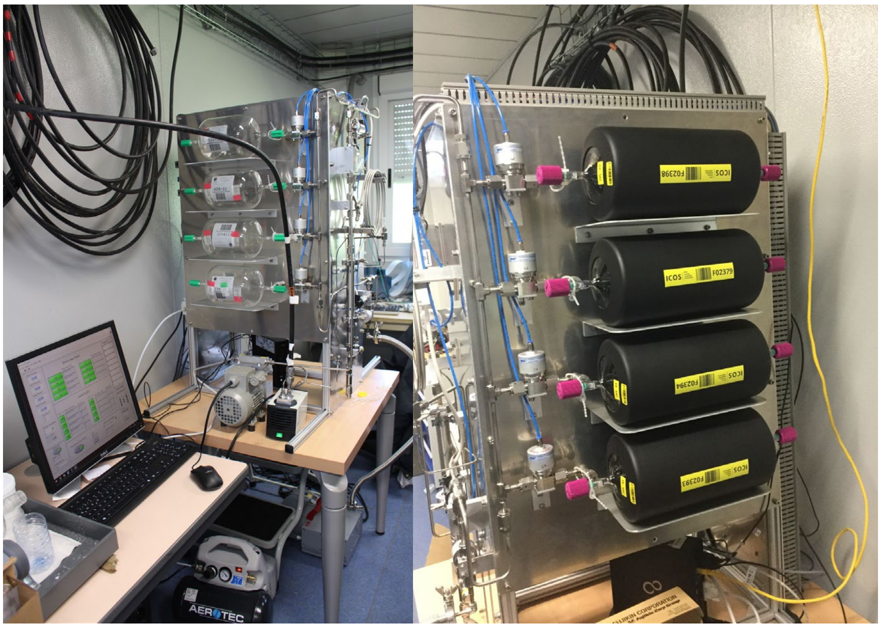

Figure 5: Installation of the UHEI flask sampler at Saclay (left) and Gonesse (right)

Figure 6: Example of an air masses going from Gonesse to Saclay, through Paris, as predicted by DWD forecast.

Beneficiary (4) UVSQ contributed to Milestone MS48 by the installation of the flask samplers at Gonesse and Saclay. 19 pairs of flasks sampled between May and mid-November 2019.

Significant results:

First measurements of the anthropogenic CO2 offset due to Paris emissions.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

There is a slight overshoot of the planned use of resources due to higher personnel costs, which, however, will be balanced by the end of the project.

Partner: 7-RUG

Description of work carried out in T1.2 by beneficiary

Beneficiary (7) RUG contributed to Milestone MS48 by continuing to collect and analyse regular flask samples from the designated stations

Significant results:

Flask samples have been collected according to the agreed criteria and strategy - in the afternoon, integrated over an hour. 12 pairs (24 flasks) have been collected and analysed from July to December 2019 (reasons for the lower number of flasks than planned are explained below). In-situ measurements

using Picarro analysers are continuously done at the stations and are compared with flask measurements every time an analysis is done.
The station 2e Maasvlakte is maintained by RUG itself, whereas the Picarro analyses and the flask sampler at Cabauw station are maintained by ECN.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions
Due to the limited occasions of favourable conditions, samples were not collected every 3 days as planned, but rather every 5-7 days (in-situ measurements with the Picarro is, of course, still going on continuously). Additionally, there have been many occasions of software and hardware failures with the sampling systems, which are caused by the motor valves controlling the opening/closing of the flasks. These issues are not constant, but an absolute solution is still difficult to be carried out and is currently being discussed with technicians in the department. There was also a connectivity issue back in September where the upwind station in Rotterdam was completely out of contact for a whole month - this was (hopefully) a one-off problem due to an unforeseen problem with a mobile network in the Netherlands (which we are using to provide connection). Plans are in place to discuss with the Rotterdam city council to let us build a(nother) proper station at the same location, as we are currently using the build of the port authority, which has been good so far but could have been improved much further to avoid occasional problems.

Partner: 7-RUGWU
Description of work carried out in T1.2 by beneficiary:
Developed an atmosphere model to compute time-series of CO2, CO and d14CO2 concentrations across Europe, in order to investigate the added value of extra measurements to better constrain the anthropogenic CO2 emissions. These computed time-series will be used in an inversion model to answer the question of which observations and what locations make the most efficient contribution for this purpose.

Task 1.3: Developing the ICOS Flask sampling strategy
List of deliverables due to be completed within this task within this reporting period:
D1.3 An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling. (M24)

Task leader: UHEI (6), Beneficiaries involved in T1.3.: ICOS ERIC (1)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS31	An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling.	WP1	5 UHEI	24	An ICOS flask sampling protocol based on historical time series and high-resolution footprint modelling

Partner: 5-UHEI
Description of work carried out in T1.3 by beneficiary
Beneficiary (5) UHEI contributed to MS31 and D1.3 by developing a flask sampling protocol for all ICOS tower stations.
Significant results:
The ICOS flask sampling strategy was a topic of discussion at all ICOS Atmosphere MSAs during the reporting period and the Deliverable Report D1.3. with the final strategy was submitted in month 28 of the project and was accepted after review in month 31. It was agreed by ICOS station PIs that the strategy for the first year of flask sampling should be as simple as possible and that at a later stage, more sophisticated targeted sampling e.g. of fossil fuel source areas in the catchment of the stations

should be implemented. All stations shall collect every three days one single flask from the highest level of their tower during noon or afternoon hours. Air sampling into the flask should be integrated over one hour. In situ measurements should be from the same level for the entire hour when the flask is sampled, which then allows direct comparison between in situ and flask concentrations as a means for quality control of the in situ observations. Test measurements at the Heidelberg pilot station showed that during low ambient concentration variability (i.e. < 1ppm for CO_2) a potential bias between flasks and in situ measurements of 0.1 ppm CO_2 could be detected from five consecutive comparisons within one month. On the two days between regular flask sampling, additional flasks should be collected; however, they should be retained for analysis only if their fossil fuel CO_2 component is likely larger than 4 ppm. Forecast of the potential fossil fuel concentration in the flask shall be based on the continuous in situ CO measurements. These data will be available the day after sampling, and a forecasting algorithm was developed by ICOS ERIC (see below). This algorithm is currently implemented in the ICOS ATC to automatically communicate such an event to the flask sampler. In the case of no such fossil-fuel CO_2 event, the flask will be marked as available for re-sampling.
Statistics about the frequency of fossil-fuel CO_2 events on the one hand and those of low-variability situations for QC purpose on the other had been evaluated for four ICOS stations based on first CO_2 and CO observations and STILT model estimates (see report of ICOS-ERIC below).
Based on Deliverable Report D1.3, a manuscript has been drafted, which will be submitted to Atmospheric Measurement Techniques (AMT) in the beginning of 2020.

Unforeseen subcontracting/in-kind contribution (if applicable)

In-kind contributions of 3 PM (1 PM male, 2 PM female) were provided by UHEI for this task during the reporting period.

Partner: 1-ICOS ERIC

Description of work carried out in T1.3 by beneficiary:

Beneficiary (1) ICOS ERIC contributed to MS31 and D1.3 by developing a flask sampling protocol for all ICOS tower stations.

Significant results:

The Carbon Portal of ICOS ERIC has developed a Jupyter notebook, which allows the evaluation of station footprints based on STILT model results. This notebook also provides comparisons of the model results and in situ observations at the stations. Together with EDGAR emission inventories, the most important fossil emission hot spots in the catchments of and their contribution to the fossil CO_2 concentration at the stations are estimated and graphically displayed. Likewise, the influence areas contributing only minor fossil signals can be determined and displayed. This tool served as the basis for the development of the flask sampling strategy described above. It has been presented in November 2019 at the ICOS MSA. It is designed to be easily used by the station PIs to characterise their site in terms of air mass influence and anthropogenic emitters in their catchment and to determine thresholds for fossil fuel CO_2 events based on model results.
The notebook delivers statistical data on the frequency of fossil events by month and for the representativeness of flask samples if collected with the strategy described above and in the delivery report D1.3.
Based on Deliverable Report D1.3, a manuscript has been drafted, which will be submitted to Atmospheric Measurement Techniques (AMT) in the beginning of 2020.

Task 1.4: Developing ICOS RI readiness to provide information on ecosystem – river – stream – estuary – ocean carbon transport and GHG fluxes

D1.4 Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system, including the possible role of ICOS RI and resulting costs to be presented to EC, ESFRI, and ICOS General Assembly. This document will also include possible cooperation with DANUBIUS RI. (M30)

Task leader: NERC (9); Beneficiaries involved in T1.4.: UNITUSCNR (1), UNITUSENEA (1), UNITUSOGS (1), UHEL (4), UHELFMI (1), LU (5), ULUND(UGOT) (1), ULUND(UUPP) (1), ETHZ (1), NERCUoE (1), NERCPML (1) UAntVLIZ (1)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS32	Conwy Catchment workshop held	WP1	8 NERC	24	Conwy Catchment workshop held
MS38	Hyytiälä Forestry Field Station workshop held	WP1	9 - UHEL	30	Hyytiälä Forestry Field Station workshop held
MS39	Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system	WP1	8 - NERC	30	Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system

Partner: 8-NERC

Description of work carried out in T1.4 by beneficiary

Beneficiary (8) NERC contributed to Milestones MS32 and MS38 and by liaising with the workshop organisers (UHEL), participating in the workshop, and chairing workshop sessions.

Beneficiary (8) NERC contributed to D1.4. and Milestone MS39 by coordinating the overall effort and generating the draft report (in progress).

Significant results:

The first draft of MS39 has been assembled and is currently being finalised.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The completed Deliverable report is delayed until the end of May 2020. This delay is caused due to the fact that to complete the work required altogether 3 different workshops. These had to be rescheduled, which also caused a delay due to participants' sea-going commitments. The workshops are completed, and during these events, a working draft of the report has been compiled. It is constructed by 40 authors that have contributed to the work, which is, therefore, causing this unexpected delay.

Partner: 3-UNITUS-CNR-ISMAR

Beneficiary 3 UNITUS_CNR (Linked third party: CNR ISMAR Trieste) contributed to:

MS32 by participating at the 2nd workshop, held the National Oceanographic Centre Southampton in the UK.

MS38 by participating at the 3rd workshop held at the Hyytiala Research Station in Finland

MS39 by writing part of the D1.4 report "Developing ICOS RI readiness to provide information on ecosystem-river-stream-ocean carbon transport and GHG fluxes."

Partner: 3-UNITUSENEA

Description of work carried out in T1.4 by beneficiary:

Beneficiary 3-UNITUSENEA contributed to D1.4. by planning an integrated atmosphere-ocean-ecosystem observatory. ENEA runs a Climate monitoring station on the island of Lampedusa (LMO; 35.5°N, 12.6°E), which is constituted by and Atmospheric Observatory (AO), contributing to the ICOS atmospheric network, and an Oceanographic Observatory (OO), located about 15 km SW of AO. The Italian national strategy has planned the implementation of measurements of ICOS marine parameters at OO, and the establishment of an ecosystem site in the Western part of Lampedusa. Within RINGO, the technical and environmental characterization of the site has been carried out, and the perspective site for the ecosystem site implementation has been identified.

These analyses contribute to Milestone MS39.

Partner: 3-UNITUSOGS

Description of work carried out in T1.4 by beneficiary

Michele Giani (UNITSOGS) participated at the Workshop 2 to *Determine the current status of European land-ocean carbon fluxes and the associated monitoring methodologies*, held in Southampton (UK),

and hosted at National Oceanographic Center Southampton, from 19th to 21st November 2018. On the second day, he participated in the breakout discussion focussed around Current Measurements of carbon fluxes and most appropriate places where European land-ocean carbon fluxes being measured. During the discussion, he also contributed to outline the gaps in the monitoring networks and discussed the methods to determine/predict where these fluxes could be particularly large and/or changing.
Moreover, he participated in the field trip aboard RV Callista, to see CTD operations used in the coastal oceanographic monitoring and to a tour of the Marine Robotics and Sensor (MARS) facility, National Oceanography Centre, Southampton. On the third day, Michele Giani contributed to the breakout and plenary discussions.
Michele Giani (UNITSOGS) participated at the Workshop 3 to *Determine the current status of European land-ocean carbon fluxes and the associated monitoring methodologies*, held at Hyytiälä, Finland at the Hyytiälä Research Station, hosted by the University of Helsinki from 5th to 8th November 2019.
During the WS he spent most of the time on constructing the D1.4 report. He participated in the Field visit to observe Eddy Covariance systems across a number of ecosystem types (wetland, lake) and forest (ICOS SMEAR II station). Participation in a break-out session led by Ivan Mammarella, which took place on Day 2 to discuss the parameters which must be measured in order to fulfill the minimum and ideal requirements of a European LOAC C flux monitoring network.
Beneficiary 3-UNITUSOGS contributed to D1.4. by writing part of the document specifically related to the Role of Eutrophication/oligotrophication and of lagoons, deltas, estuaries in the land ocean C fluxes, Monitoring strategies, and Integrating ICOS infrastructure with other RI as Danubius and eLTER.
Beneficiary 3-UNITUSOGS contributed to:
Milestone MS32 by participating in the 2nd workshop held at National Oceanographic Centre Southampton in UK,
MS38 by participating at the 3rd Workshop held at Hyytiälä Research Station in Finland and to
MS39 by writing part of the D1-4 report.
Significant results:
Proposed integration between different networks ICOS, Danubius, and E-LTER in order to optimize the efforts to quantify the Carbon fluxes from land to ocean.

Partner: 9-UHEL
Description of work carried out in T1.4 by beneficiary
Beneficiary (9) UHEL contributed to Milestone MS32 by participating to the Workshop at NOS in Southampton (UK), to MS38 by hosting the Workshop in Hyytiälä (Finland), and to MS39 by writing few chapters of the report.
Significant results:
UHEL has contributed in particular to chapter's report related to description of carbon cycle related processes in lake and wetland ecosystems, as well as to the definition of standard methods for fluxes and meteorological measurements over water bodies such lakes and sea.

Partner: 9-UHELFMI
Description of work carried out in T1.4 by beneficiary
Beneficiary 3-UHELFMI contributed to the Milestone MS32 by participating at the 2nd workshop held at the National Oceanographic Centre Southampton in the UK, MS38 by participating at the 3rd Workshop held at the Hyytiälä Research Station in Finland and MS39 by writing part of the D1.4 report.
Significant results:
UHELFMI has contributed in particular to chapter's report related to the description of carbon cycle related processes in ground waters and lake and wetland ecosystems, as well as to the definition of standard methods for fluxes and meteorological measurements over water bodies such lakes and sea.

Partner: 10-ULUND
Description of work carried out in T1.4 by beneficiary:

Beneficiary 10-LU contributed to D1.4. by participating in annual meetings and in the workshops. Beneficiary 10-LU contributed to Milestone MS32, MS38, and MS39 by participating in workshops and by participating in discussions following the workshops.

Significant results:

Lindroth presented a new innovative method for continuous measurement of surface water CO2 and CH4 concentrations at the workshop in Southampton in March 2019. Results from a field campaign in northern Finland demonstrated the feasibility of the system. A publication describing the system is planned after some additional laboratory tests and calibrations.

Partner: 10-ULUND (UGOT)

Description of work carried out in T1.4 by beneficiary:

Beneficiary 10-ULUND (UGOT) contributed to MS32 by participating at the 2nd workshop held at the National Oceanographic Centre Southampton in the UK, MS39 by writing part of the D1.4 report. “PROTOCOL FOR EDDY-COVARIANCE FLUXES and METEO MEASUREMENTS OVER WATER BODIES.”

Partner: 10-ULUND (UUPP)

Description of work carried out in T1.4 by beneficiary:

Beneficiary 10-ULUND(UUPP) contributed to D1.4. and Milestone MS32, MS38 and MS39 by participating in the discussion concerning EC methodology over a variety of water surfaces. Discussion includes problems related to EC-measurements in marine and aquatic environments and relevant complementary parameters. This work was done on workshops, virtual meetings, and by contributing to virtual documents.

Partner: 8-NERCPML

Description of work carried out in T1.4 by beneficiary:

Milestone MS32 by participating at the 2nd workshop held at the National Oceanographic Centre Southampton in UK,

MS38 by participating at the 3rd Workshop held at the Hyytiälä Research Station in Finland and

MS39 by writing part of the D1.4 report

Task 1.5: Enhancing the bridge between ICOS RI and satellite observations

List of deliverables due to be completed within this task within this reporting period:

D1.5 Scientific-technical Concept for the integration of European TCCON sites into ICOS and resulting costs. (M30)

D1.6: Ocean-atmosphere flux NRT data calculation routine, including satellite data streams on surface temperature, skin effects, wave state, and wind speeds. [30]

Task leader: UVSQ (10); Beneficiaries involved in T1.5.: UNITUSINRA (1), RUG (4), UBremen (8), NERCUoE (9), UAnt (12) BIRA (4)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS40	Forest ground Lidar measurements completed	WP1	12 - UANTWERPEN	30	Forest ground Lidar measurements completed
MS41	Scientific-technical concept for the integration of European TCCON sites into ICOS	WP1	4 - UVSQ	30	Scientific-technical concept for the integration of European TCCON sites into ICOS

MS42	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational	WP1	8 - NERC	30	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds operational
MS48	Samples of ffCO2 emissions from all stations analysed	WP1	5 - UHEI	34	Samples of ffCO2 emissions from all stations analysed
MS50	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available	WP1	12 - UANTWERPEN	36	Pilot retrieval for calibrating satellite biomass data with ground Lidar measurements available

Partner: 4-UVSQ
Description of work carried out in T1.5 by beneficiary:
Beneficiary 4-UVSQ contributed to Task 1.5 by leading the writing of the deliverable D1.5 “Scientific-technical Concept for the integration of European TCCON sites into ICOS and resulting costs” and by organising meetings and teleconferences to co-ordinate the production of D1.5.
Beneficiary 4-UVSQ contributed to Milestones MS8 and MS20, by organising two “TCCON and ICOS data integration” workshops.
All the above-mentioned contributions were provided in close collaboration with 26-BIRA and 24-UBremen.
Significant results:
Deliverable 1.5 submitted and accepted.

Partner: 3-UNITUSINRA
Description of work carried out in T1.5 by beneficiary:
Beneficiary 3-UNITUSINRA contributed to Milestone MS40 and MS50 by making its own terrestrial Lidar available for U Antwerpen, sending LIDAR images for testing, and participate otherwise to the overall discussion, meetings, and presentations.
Significant results:
See Partner U-Antwerpen 12.

Partner: 7-RUG
Description of work carried out in T1.5 by beneficiary:
Beneficiary 7-RUG contributed to D1.5 and MS41 by contributing to the development of the future framework of the data center for TCCON, the calibrations of TCCON total column retrievals, and the validation of the new vertical profile retrievals from two TCCON sites.
Significant results:
The AirCore observations in Sodankyla, Finland, were used to evaluate the CH_4 retrievals. Following the intensive AirCore campaign in Sodankyla in June 2018, RUG and LSCE coordinated a second intensive campaign in Trainou, France, in June 2019. The Trainou campaign tested multiple launches of AirCores with a payload weight of 2-3 kg, which also meets the aviation regulations on balloon flights in most European countries. Data from both campaigns are being analysed, and compared. We aim to understand the differences and improve the AirCore technique in both the sampling and data retrieval processes.
Besides this, RUG developed the concept of AirCore in future ICOS and presented it during the ICOS-TCCON workshop in Prague in 2018: 1) AirCore provides complementary, vertical profile information to the ICOS Atmosphere domain; 2) AirCore provides a calibration of TCCON retrievals to the WMO scales.

Partner: 24-UBremen
Description of work carried out in T1.5 by beneficiary:
Beneficiary 24-UBremen contributed to Milestone MS41 and Deliverable D1.5. by developing a concept for the European TCCON integration into ICOS by taking the demands from the TCCON (global as well as European) and ICOS side into account, establishing a cost estimate for the integration of the European TCCON into ICOS and by discussing the concept document and the cost estimate of the

integration of the European TCCON into ICOS during the annual TCCON meeting in Wanaka, New Zealand with the global TCCON community. UBremen wrote the concept document.
All the above-mentioned contributions were provided in collaboration with BIRA and LSCE.

Significant results:

Deliverable 1.5 submitted and accepted.

Partner: 8-NERCUoE

Description of work carried out in T1.5 by beneficiary:

Beneficiary 8-NERCUoE wrote deliverable D1.6 and the accompanying software tools. Additional tools to enable the routine and automatic downloading of ancillary data to enable global air-sea gas flux calculations (eg wind speed data, sea surface temperature) were written, and these are available as open source tools (BY-NC). The deliverable D1.6 explains how to use these tools and includes step by step instructions. A download link to the tools is here: https://github.com/oceanflux-ghg/FluxEngineAncillaryTools
These tools include methods to re-analyse the SOCAT database to a common and referenceable sea surface temperature dataset which is required to enable an accurate air-sea gas flux calculation. SOCATv2019 has been re-analysed using this method, and these data are freely (BY-NC) available (Holding et al., 2019a).
Beneficiary 8-NERCUoE completed Milestone MS42 by extending, verifying, and publishing the Version 3 update to the FluxEngine open source (BY-NC) air-sea flux software toolbox which is publicly available here: https://github.com/oceanflux-ghg/FluxEngine

This update to the toolbox is accompanied by a journal publication (Holding et al., 2019) and interactive tutorials are packaged with the toolbox that use iPython.

Holding T, Ashton I, Shutler J (2019a). Reanalysed (depth and temperature consistent) surface ocean CO_2 atlas (SOCAT) version 2019, doi: 10.1594/PANGAEA.905316
Holding T, Ashton IG, Shutler JD, Land PE, Nightingale PD, Rees AP, Brown I, Piolle J-F, Kock A, Bange HW, et al (2019b). The FluxEngine air-sea gas flux toolbox: simplified interface and extensions for in situ analyses and multiple sparingly soluble gases. Ocean Science, 15(6), 1707-1728

Significant results:

D1.6 has been accepted.

Partner: 12-UAnt

Description of work carried out in T1.5 by beneficiary:

Beneficiary 12-UAnt contributed to Milestone M40 and M50 by developing the draft for the TLS measurements in at the ICOS sites, testing the field protocol at 6 ICOS sites, conducting a field campaign at six ICOS sites, scanning all permanent forest plots with the Lidar scanner and by organizing a conference on TLS measurements in the forest, bringing together all the experts in the field: "TLS in forest ecology - expanding the horizon", May 6-7 2019, Ghent.

Significant results:

Since the last reporting period, we have worked on refining the QSM algorithms in order to extract volumes from the point clouds that we were made at the three sites in Belgium. Each of the 60 trees was cut from the point clouds so that the volumes could be compared between the TLS and the destructive measurements. Preliminary results show an overestimation of 33% from the TLS compared to the destructive measurements.

Figure 7: Example of a single tree extraction from the point cloud (left) and fitted QSM (right)

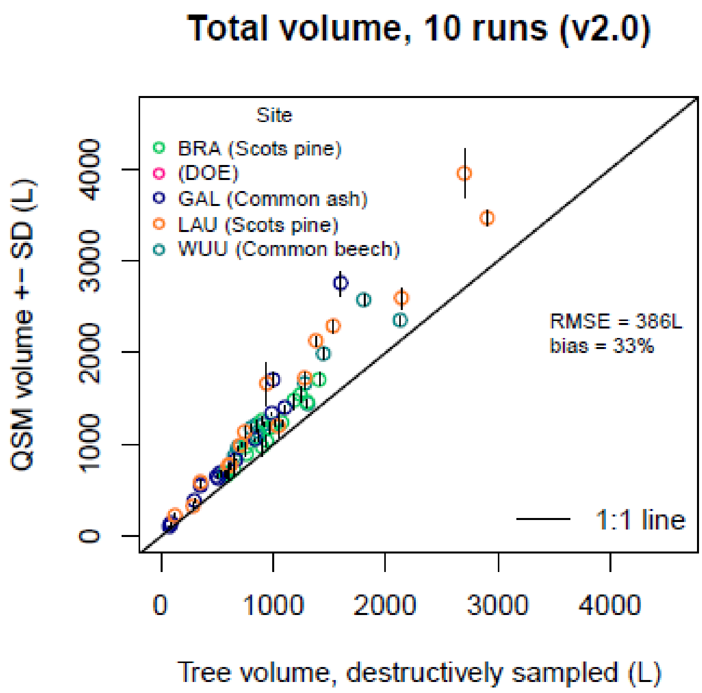

Figure 8: First results of the comparison of volumes derived by the QSM and destructive measurements of the 60 destructively sampled trees at five sites in Belgium.

A more detailed analysis showed that the volume estimation of the stems from the TLS scans gave good results, however, we discovered an overestimation in the fine branches (>3rd branching order).

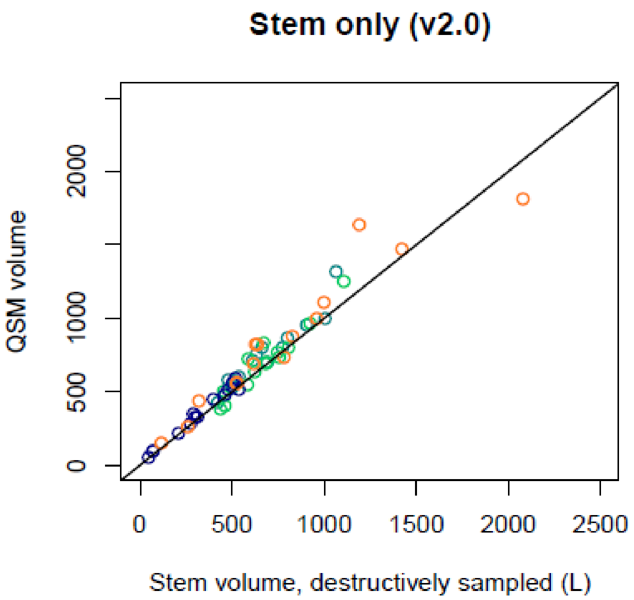

Figure 9: first results of the comparison of stem volumes derived by the QSM and destructive measurements of the 60 destructively sampled trees at five sites in Belgium.

The next steps, we will first focus on the further optimization/parametrisation of the QSM algorithms and investigating the possible causes for the difference between the destructive volumes and the volumes derived from the TLS point clouds.
In addition to the processing of the TLS data a large field campaign was set up to scan a subset of ICOS sites with the TLS. In total six station were scanned: Fontainebleau (FR-Fon), Hohes Holtz (DE-Hoh), Svartberget (SE-Svb), Norunda (SE-Nor), Hyltemossa (SE-Htm) and Hyytiälä (FI-Hyy). All sites were scanned according to the protocol that was developed and tested at the sites.

Partner: 26-BIRA
Description of work carried out in T1.5 by beneficiary:
Beneficiary 26-BIRA contributed to D1.5. and to Milestone MS41:
As reported by beneficiary UBremen, BIRA worked together with them on developing and writing the concept document for the integration of TCCON into ICOS. It contributed to the preparation of the cost estimate tables and the discussion during the annual workshop at Wanaka, New Zealand, with the global TCCON community. In more detail, BIRA contributed by:

- Developing a concept for the integration of the European TCCON stations into ICOS
- Meetings and discussions with global as well as European TCCON PIs to discuss on the issues related to the integration
- Discussions with the European TCCON PIs on their participation to the ICOS infrastructure and the tasks distribution between the European TCCON representatives
- Discussions with the ICOS ATC to integrate the ICOS viewpoint into the concept document.
- Establishing a cost book for the Reunion Island TCCON station
- Establishing a cost book for the central facility of the European TCCON
- Discussing the concept document and the cost estimate of the integration of the European TCCON into ICOS during the annual TCCON meeting in New Zealand with the global TCCON community
- Writing of the concept document

Significant results:
Deliverable 1.5 has been submitted and accepted.

Work Package 2: Enhancing ICOS membership and sustainability

Summary
The main objectives of WP2 are:
• to foster capacity-building in Research Infrastructure management, related scientific knowledge and Research Infrastructure human capital development in relevant regions.

• to enlarge the ICOS membership to increase the geographical coverage of the ICOS observations.

• to train new ICOS members to be fully in line with ICOS technical and scientific standards.

All the above-mentioned objectives have been successfully addressed. It can be briefly summarised, based on the collaboration with all the WP2 members, that various capacity-building activities were done, near future enlargement of ICOS have been successfully negotiated and prepared for two new countries (Estonia and Spain) and training activities (including training materials) have been prepared.
The work carried out in WP2 during the second reporting period (M19–M36) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

WP2 consists of the two parts - ICOS ERIC part (ICOS HO, UVGZ, UiB, UNITUS, UVSQ) and ICOS ERIC candidate and partner countries (INOE, OMSZ, ULPGC, NOA, NUID UCD, EULS, ISA, WITS, PULS). The former group focuses mainly on knowledge transfer and capacity building support and provision, and the latter group, those are the beneficiaries of the WP2 goals. However, feedback and two-way communication are kept and supported. That is why several below described activities of the involved RINGO project partners are done together and formally is duplicated reported. Each beneficiary contributed to the printed and online ICOS handbook versions. Therefore, as an acknowledgment of this significant contribution, they were also listed as beneficiaries in this second periodic report, even though they were not mentioned in the original DoA at the proposal.

List of deliverables due to be completed within this task within this reporting period:
D2.1 Report on enhancing membership strategy for ICOS ERIC, including the online Handbook for Stakeholders. (M24)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS34	Report on enhancing membership strategy for ICOS ERIC finalized	**WP2**	6 - UVGZ	24	Report on enhancing membership strategy for ICOS ERIC finalized
MS43	Virtual training platform completed, all training material uploaded	**WP2**	6 - UVGZ	30	Virtual training platform completed, all training material uploaded
MS51	Second summer school providing scientific training for new countries held	**WP2**	6 - UVGZ	36	Second summer school providing scientific training for new countries held

Contributions per task:
Task 2.1: Enhancing ICOS membership and sustainability
Task leader: ICOS ERIC (4)
Beneficiaries involved in T 2.1: ICOS ERIC (4), UVGZ, UiB, UNITUS, UVSQ, INOE, OMSZ, ULPGC, NOA, NUID UCD, EULS, ISA, WITS, PULS.
List of deliverables due to be completed within this task within this reporting period:

D2.1 Report on enhancing membership strategy for ICOS ERIC, including the online Handbook for Stakeholders. (M24)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS34	Report on enhancing membership strategy for ICOS ERIC finalized	**WP2**	6 - UVGZ	24	Report on enhancing membership strategy for ICOS ERIC finalized

Partner: 1-ICOS ERIC

Description of work carried out in T2.1 by beneficiary:

Beneficiary (1) ICOS ERIC contributed to D2.1. "Report on enhancing membership strategy for ICOS ERIC" and to Milestone MS34 by coordinating the work in Task 2.1 with a significant effort on the ICOS Handbook designed for a large variety of stakeholders in new countries. This document, published in 2019, is a major source of information on ICOS, its science case, its structure and its functioning. It includes a description of each of the currently 12 networks of stations in ICOS and some guidelines for countries wanting to join ICOS. More broadly, Deliverable 2.1 describes how ICOS ERIC should manage its current members and attract new ones. It suggests actions and processes to be implemented towards new countries.

Significant results:

The ICOS Handbook is available on the website of ICOS:
www.icos-ri.eu/sites/default/files/cmis/ICOS%20Handbook%202019.pdf

Together with the active work led by ICOS, this allowed for significant improvements with countries like Estonia and Poland, but also with deeper discussions with Hungary. It also made it possible for Spain to announce, in December 2019, that the country would join ICOS during the year 2020.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

Deliverable 2.1 is delivered with a significant delay, which is mostly due to changes in the organization of ICOS ERIC that occurred at the end of 2018. Key personnel left ICOS, and the team in charge of Task 2.1 had to be reorganized. The amount of work for the preparation of the ICOS Handbook was also larger than expected, but the final result is meeting all the requirements that had been set on this work.

Partner: 2-UiB, 3-UNITUS, 4-UVSQ, 6-UVGZ, 13-INOE, 14-OMSZ, 15-ULPGC, 16-NOA, 17-NUID UCD, 18-EULS, 19-ISA, 20-WITS, 21-PULS

Description of work carried out in T2.1 by beneficiaries:

All the beneficiaries mentioned above contributed to D2.1. by updating the questionnaire addressed to the ICOS candidate and partner countries. The questionnaire outcomes were used, among others, for the finalisation of the task T2.1.

Beneficiaries contributed to the task development by sharing its experience in the RINGO project events (especially RINGO annual meetings and RINGO Executive Board sessions). Additionally, they provided their feedback on the developed document.

Beneficiaries contributed to Milestone MS34 by taking part in preparing the report on enhancing membership strategy for ICOS ERIC.

Significant results:

See above.

Task 2.2: Support in building national network and training for managers in stakeholder liaison and resource acquisition

Task leader: UVGZ (24); Beneficiaries involved in T 2.2: INOE (1), OMS (3), ULP (1), NOA (2), NUID UCD (2), NCES EMU (1), ISA (1), UWWR (1), PULS (1)

Partner: 6-UVGZ

Description of work carried out in T2.2 by beneficiary

As a preparation for the training needs, a questionnaire addressed to ICOS candidate and partner countries was updated in collaboration with ICOS ERIC Head Office. The questionnaire, among others, updated relevant contacts on the RIs stakeholders of the ICOS candidate countries and collected information on the current state of the RI development. The outcomes of the questionnaire and communication with the representatives of candidate and partner ICOS countries contributed to foster the national community-building in countries relevant to ICOS and advocating of GHG research and high-level interaction with stakeholders to bring forward the benefits of joining ICOS. The questionnaire outcomes were shared in collaboration with ICOS Head Office in the ICOS community and presented and discussed with the RINGO participants at the Brno RINGO Summer School in September 2019 (see more below in the description of work in T2.3). The questionnaire outcomes are planned to be discussed in the RINGO Annual meeting in Poznan in March 2020. The questionnaire was utilised further in MS34, where the outcomes were used as one input source for the finalisation of the Report on enhancing membership strategy for ICOS ERIC.

To support the building of national networks in ICOS candidate countries, a specific training (focused mainly on funding opportunities supporting research infrastructures) for managers and other relevant stakeholders of these countries was organised by UVGZ and in collaboration with ICOS ERIC, UiB, UNITUS, and UVSQ in the RINGO 3rd Annual Meeting in Southampton. Training materials were uploaded to a virtual training platform. When communicating the preparation and publication of the training materials within ICOS community (e.g. during RINGO events or ICOS General Assemblies), it has been revealed that the published WP2 training materials are also relevant to the current ICOS members needs (for example for national research roadmap evaluations, for the training of the early-stage researchers, sharing the best practices etc.).

During the course of the project, mainly UVGZ, ICOS Head Office and ICOS central facilities (represented in RINGO project by UiB, UNITUS, and UVSQ) continued in the provision of tailor-made consultations and lessons (mainly via online communication, during RINGO and ICOS events, or specific visits) to the candidate countries addressing “hot issues” related to the national ICOS Research Infrastructure establishment in these countries and their ICOS ERIC membership. For example, Hungarian partners (represented in RINGO by OMSZ) consulted with UVGZ project on GHGs measurements by using soil chamber techniques according to the ICOS standards.

OMSZ also consulted preparation of a national research infrastructure consortium for Hungarian roadmap application (UVGZ also communicated the agenda with the National RDI Office responsible for ESFRI Ms. Gyorgyi Juhasz in Brussels, 27.11.2019).

INOE consulted with UVGZ during 2019 technical issues related to the construction of the atmospheric tower station in Romania.

South African representative Wim Hugo consulted ICOS ecosystem research infrastructure sites operation and related data management during his visit to UVGZ on 24.9.2019.

INOE with UVGZ organised national research infrastructure consortium meeting in Bucharest 7 May 2019, where were discussed mainly administrative issues related to ICOS ERIC accession, and UVGZ also shared its experience with EU structural funding dedicated to the research infrastructure development.

NOA visited UVGZ on 14 December 2018 and consulted ICOS atmospheric station labelling process and related technical issues.

PULS representative visited UVGZ and consulted the ICOS ecosystem stations labelling process with UVGZ on 19.7.2018.

Apart that, during The 3rd ICOS International Conference organised in Prague 11.9.-14.9.2018 excursions to the UVGZ ecosystem and atmospheric ICOS sites were organised. The excursions were also participated by conference participants from the ICOS candidate and partner countries.

Some of these provided consultations are also reported below from the individual RINGO participant perspective.

Significant results:

RINGO project contribution to geographical ICOS enhancement (Estonia and Spain becoming new ICOS ERIC members soon) and research infrastructure development of the ICOS candidate and partner countries.

Training materials used not only by the RINGO WP2 members but also by various ICOS community members and stakeholders.
Provision of the tailor-made consultations appreciated by the WP2 beneficiaries.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

During the implementation of T2.2 more PMs, than initially foreseen by the DoA, have been needed, because based on the communication with the ICOS candidate and partner countries, more inputs from UVGZ administrative and technical staff were asked instead of senior experts (higher demand on administrative and technical issues). However, this does not exceed the planned personal costs UVGZ allocation, because of the lower average costs of UVGZ technicians and administrators enable a higher number of PMs.

Partner: 13-INOE

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. INOE consulted with UVGZ during 2019 technical issues related to the construction of the atmospheric tower station in Romania. INOE with UVGZ organised national research infrastructure consortium meeting in Bucharest 7 May 2019 where were discussed mainly administrative issues related to ICOS ERIC accession, and UVGZ also shared its experience with EU structural funding dedicated to the research infrastructure development.

Significant results:

See above.

Partner: 14-OMSZ

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. OMSZ consulted preparation of a national research infrastructure consortium for Hungarian roadmap application. GHGs measurements by using soil chamber techniques according to the ICOS standards project preparation was consulted with UVGZ.
Participation at RINGO Annual Scientific Meeting, Southampton, UK, 20-22 March 2019, Dr. Györgyi Baranka

Significant results:

See above.

Partner: 15-ULP

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings and consultations.
During this period, several meetings were carried by video-conference among the responsible for the atmospheric, oceanic, and ecosystems stations inside ICOS Spain with participation also of other members of ICOS-Spain. Moreover, the PI focalized his efforts putting together the President of the Canary Islands Government and the Spanish Ministry for the Ecological Transition, who both indicated the interest in becoming ICOS members, and confirming that the Spanish Meteorological Organization will be the one paying the Spanish Contribution to ICOS membership. The PI organized in Madrid a meeting to establish the starting process, the selection of the stations able to achieve ICOS standards on July 19 with the presence of the General Director and Sub director of Internationalization of Science and Innovation of the Ministry of Science and the Director of AEMET. The official presentation of this decision took place in the special session of the COP25 where ICOS had its special event, where the PI was also present.

Significant results:

Spain will be ICOS member by January 2021

Partner: 16-NOA

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. NOA visited UVGZ on 14 December 2018 and consulted ICOS atmospheric station labelling process and related technical issues.

In collaboration with LSCE, NOA initiated GHGs measurements in Athens (December 2018) and continued GHGs measurements at the regional background site of Finokalia-Crete. Two articles on GHGs conducted at these locations are in preparation, and two abstracts were submitted to international conferences. This is the first time that long-term measurements of GHGs have been performed in the Eastern Mediterranean at both urban and background locations.

A Greek ICOS related meeting was conducted at Heraklion Crete in September 2019 to bring together all ICOS related Greek scientists. In addition, several meetings were performed with the Ministry to express the interest of the Greek community to participate in the ICOS-RI.

Significant results:

See above.

Partner: 17-NUID UCD

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings and consultations. Organisation of the national meeting in December 2019 to discuss future Irish involvement in ICOS ERIC.

Significant results:

See above.

Partner: 18-EULS

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations.

Significant results:

See above.

Partner: 19-ISA

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. A national research infrastructure, PORBIOTA was set up in Portugal. PORBIOTA includes different research domains such as biodiversity, genetics, and environmental metagenomics, ecosystem monitoring, and biosphere-atmosphere greenhouse gases exchange.

All participants to the infrastructure are engaged in a collaborative effort to establish useful collaborations among different research areas and attract researchers to collaborate.

RINGO funds have been applied to support in collaboration with the ICOS community two workshops of eddy covariance users in Portugal, which joined researchers from the University of Aveiro, Èvora, and Lisbon (IST and ISA). The first workshop was realized on July 23, the second on December 5, 2019.

Significant results:

See above.

Partner: 20-WITS

Description of work carried out in T2.2 by beneficiary

Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. South African representative Wim Hugo consulted ICOS ecosystem research infrastructure sites operation and related data management during his visit to UVGZ on 24.9.2019.

Significant results:

See above.

Partner: 21-PULS
Description of work carried out in T2.2 by beneficiary
Updating of the RINGO questionnaire and related collection and provision of the information on the current state of the RI development at the national level. Participation at RINGO events, trainings, and consultations. PULS representative visited UVGZ and consulted the ICOS ecosystem stations labelling process with UVGZ on 19.7.2018.
Significant results:
See above.

Task 2.3: Training workshops for scientists in candidate countries.

Task leader: UVGZ (12); Beneficiaries involved in T 2.3: ICOS ERIC (2), UiB (3), UNITUS (4), UVSQ (4), INOE (1), OMS (3), ULP (1), NOA (2), NUID UCD (1), NCES EMU (1), ISA (1), UWWR (1), PULS (1)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS43	Virtual training platform completed, all training material uploaded	**WP2**	6 - UVGZ	30	Virtual training platform completed, all training material uploaded
MS51	Second summer school providing scientific training for new countries held	**WP2**	6 - UVGZ	12	Second summer school providing scientific training for new countries held

Partner: 6-UVGZ
Description of work carried out in T2.3 by beneficiary
The work in this task continued towards the D2.5 (M42) by organising of other two of three scheduled RINGO summer schools. Beneficiary (6) UVGZ contributed to D2.5 by organisational contribution (mainly dissemination and communication with W2 RINGO participants including consultation training needs of the ICOS candidates, training content and preparation of training materials) of the RINGO summer school “Underway CO2 data and metadata quality control procedures” that was organised in Sopoty (Poland) on 1.4.- 3.4.2019. It was organised in collaboration with ICOS Ocean Thematic Centre (represented by IOW) and IOPAN (The Institute of Oceanology). This activity was also open for scientists and technicians from the existing ICOS networks, and this was very appreciated by the ICOS candidate countries because this brings more experience and knowledge share and transfer. This type of collaboration ensures the effective transfer of the expertise and contributes to the scientific readiness of the ICOS candidate countries and the future technical and scientific cooperation. UVGZ reflected the outcomes of the training school, based mainly on the report of the summer school for the purposes of the next RINGO trainings and summer schools.
UVGZ organised in collaboration with ICOS ERIC Head Office and ICOS Central Facilities (represented in RINGO by UiB, UNITUS, UVSQ) and hosted RINGO summer school from 16th to 20th September 2019. The main goal of the summer school itself was the transfer of knowledge to scientists and PhD students in GHG research, and outside the ICOS community. The trainees from Hungary, Poland, Estonia, and Slovakia attended trainings about building and operating an ICOS station and then about data obtaining and processing. Another important part of the school were field trainings at ICOS UVGZ Atmospheric Station Křešín u Pacova and ICOS UVGZ ecosystem station floodplain forest Lanžhot. These field trips with hands-on trainings were an opportunity to see the ICOS stations in practice. There was also organised a training excursion to UVGZ laboratories located in Brno. Apart from these formal parts of the training, there was also time for informal consultations and discussions for the trainees to make contact with each other and with the CzechGlobe scientific community, which will help in the future collaboration.

The RINGO summer school experience within the presentation of the RINGO project was presented at several international events e.g. Day of National Research Infrastructures 2018 (Session IV: Assessment of Research Infrastructures) in Ostrava, CZ, on 6.11.2018; Improving European Charter of Access to Research Infrastructures from the perspective of responsible research and innovation approach Workshop in Brussels, BE, on 25.9.2019; 10th Danube Academies Conference in Prague, CZ, on 31.10.2019.
Beneficiary (6) UVGZ contributed to Milestone MS43 and MS51
UVGZ contributed to Milestone MS43 by preparation and upload of the various training materials (including also training materials prepared for RINGO Summer schools) to on-line platform EMDESK.
UVGZ contributed to Milestone MS51 by organisational contribution of the summer schools and as the main organizer of the RINGO Summer School in the CZ in September 2019.

Significant results:

The summer school and trainings received very positive feedback from the trained participants and already now it is successfully reached the deliverable D2.5 (Organisation of at least three training workshops and summer schools for the ICOS candidate representatives and other participants oriented on the scientific content related to the ICOS research infrastructure establishment and operation) that is due project month 42 (MS63).

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

During the implementation of T2.3, more PMs than initially foreseen by the DoA have been needed, because based on the communication with the ICOS candidate and partner countries, more inputs from UVGZ administrative and technical staff were asked instead of senior experts (higher demand on administrative and technical issues). However, this does not exceed the planned personal costs UVGZ allocation because of lower average costs of UVGZ technicians and administrators enable a higher number of PMs.

Partner: 2-UiB

Description of work carried out in T2.3 by beneficiary

Organisation in collaboration with UVGZ and ICOS ERIC Head Office and ICOS Central Facilities RINGO summer school from 16th to 20th September 2019 (see above). Training materials and consultations provision.
Beneficiary (2) UiB contributed to Milestone MS43 by preparation of the various training materials (including also training materials prepared for RINGO Summer schools) to on-line platform EMDESK.
Beneficiary (2) UiB contributed to Milestone MS51 by an organisational contribution of the summer schools.

Significant results:

See above.

Partner: 3-UNITUS

Description of work carried out in T2.3 by beneficiary

Organisation in collaboration with UVGZ and ICOS ERIC Head Office and ICOS Central Facilities RINGO summer school from 16th to 20th September 2019 (see above). Training materials and consultations provision.
Beneficiary (3) UNITUS contributed to Milestone MS43 by preparation of the various training materials (including also training materials prepared for RINGO Summer schools) to on-line platform EMDESK.
Beneficiary (3) UNITUS contributed to Milestone MS51 by an organisational contribution of the summer schools.

Significant results:

See above.

Partner: 4-UVSQ

Description of work carried out in T2.3 by beneficiary

Organisation in collaboration with UVGZ and ICOS ERIC Head Office and ICOS Central Facilities RINGO summer school from 16th to 20th September 2019 (see above). Training materials and consultations provision.

Beneficiary (4) UVSQ contributed to Milestone MS43 by preparation of the various training materials (including also training materials prepared for RINGO Summer schools) to on-line platform EMDESK.
Beneficiary (4) UVSQ contributed to Milestone MS51 by an organisational contribution of the summer schools.
Significant results:
See above.

Partner: 13-INOE
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (13) INOE contributed to Milestone MS43 and MS51 by use of the RINGO training materials, and training materials feedbacks provisions.
Significant results:
See above.

Partner: 14-OMSZ
Description of work carried out in T2.3 by beneficiary
Beneficiary (14) OMSZ contributed to Milestone MS43 and MS51 by use of the RINGO training materials, training materials feedbacks provisions, and by the participation of Viktor Dezsi and Balint Pete in the RINGO summer school in the Czech Republic, 16-20 September 2019.
Significant results:
See above.

Partner: 15-ULP
Description of work carried out in T2.3 by beneficiary
Beneficiary (15) ULP contributed to Milestone MS43 and MS51 by use of the RINGO training materials and training materials feedbacks provisions.
During this period, responsible at the different stations have continued updating their equipment to ICOS standards and establishing stations with ICOS requirements to be able to become ICOS stations. The expertise in previous work and stations have been applied with internal courses for master and technical students. None from Spain has directly participated in training workshops.
Significant results:
Spain is working to have their stations ready to start with labelling as soon as we will become member.

Partner: 16-NOA
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (16) NOA contributed to Milestone MS43 and MS51 by use of the RINGO training materials and training materials feedbacks provisions.
Significant results:
See above.

Partner: 17- NUID UCD
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (17) NUID UCD contributed to Milestone MS43 and MS51 by use of the RINGO training materials and training materials feedbacks provisions.
Significant results:
See above.

Partner: 18-EULS
Description of work carried out in T2.3 by beneficiary
See activity reported above.

Beneficiary (18) EULS contributed to Milestone MS43 and MS51 by use of the RINGO training materials, training materials feedbacks provisions, and by the participation of Dmitrii Krasnov in the RINGO summer school in the Czech Republic, 16-20 September 2019.
Significant results:
See above.

Partner: 19-ISA
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (19) ISA contributed to Milestone MS43 and MS51 by use of the RINGO training materials and training materials feedbacks provisions.
Significant results:
See above.

Partner: 20-WITS
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (20) WITS contributed to Milestone MS43 and MS51 by use of the RINGO training materials and training materials feedbacks provisions.
Significant results:
See above.

Partner: 21-PULS
Description of work carried out in T2.3 by beneficiary
See activity reported above.
Beneficiary (21) PULS contributed to Milestone MS43 and MS51 by use of the RINGO training materials, training materials feedbacks provisions, and by the participation of Kamila Harenda, Damian Józefczyk, Patryk Poczta in the RINGO summer school in the Czech Republic, 16-20 September 2019.
Significant results:
See above.

Work Package 3: Technical developments

Summary
The main objective of WP3 is to explore the technological necessities to enable the scientific concepts developed in WP 1. It comprises technical pilot studies or workshop-based conceptual studies that will provide clear guidance for further technical innovations within ICOS. The short summary of the main achievements are: i) although delayed from the original schedule, considerable progress has been made in developing and testing the autonomous systems to measure the partial pressure of CO_2 in ocean surface waters on commercial carrier ships; ii) Trainou campaign (France) was organized for extensive profile measurements of CO_2, CH_4, CO, COS and N_2O concentrations; iii) a self-contained, low power and volume instrument for accurate measurement of air and surface water pCO_2 was built and lab- and field-tested to be suitable for integration into a waveglider; iv) all necessary information and results for the state-of-art non-CO_2 eddy-covariance measurements are available and the writing of a report “Protocol on non-CO_2 eddy-covariance measurements, QA/QC, data processing and gap-filling” is in progress; v) the analysis of the temporal and spatial variations in CO_2 fluxes was carried out for gross primary productivity (GPP) based on data from almost 150 flux towers and a quantitative attribution to the increasing CO_2 concentration was achieved.
The detailed description of the work carried out in WP3 during the second reporting period (M18-M36) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

List of deliverables due to be completed within this task within this reporting period:

D3.2 Report on implementation and technical realization of atmospheric measurements on the three VOS platforms (M20)
D3.4 : Technological handbook and assessment report on CO_2-ASV. [36]
D3.5: Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling. [36] Protocol for eddy covariance measurements of CH_4 and N_2O fluxes, QA/QC, data processing and gap-filling (Month 36)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS52	High accuracy in-situ vertical profile measurements completed	WP3	7 - RUG	**36**	High accuracy in-situ vertical profile measurements completed
MS29	CO_2 instrument build and incorporated into an ASV to make an ASV-CO_2 vehicle	WP3	23 – GEOMAR	20	CO_2 instrument build and incorporated into an ASV to make an ASV-CO2 vehicle
MS44	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms	WP3	27 –IOW	30	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms
MS53	Technological Handbook and Assessment Report on CO_2- ASV		23 – GEOMAR	36	Technological Handbook and Assessment Report on CO_2- ASV
MS54	Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling completed	WP3	9 - UHEL	36	Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling completed
MS35	International workshop on enhancing ICOS Ecosystem sites to become sentinel sites in cooperation with other domain-specific ESFRI and global infrastructure held	WP3	3-UNITUS	24	This MS will be finalised as a side event to ICOS science conference

Contributions per task:

Task 3.1: Exploration to apply new technologies for vertical profiles

Task leader: RUG (6); Beneficiaries involved in T 3.1: UVSQ (6), GUF (5), UBremen (5), UHELFMI (5), ETHZUBern (2), BIRA (4).

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS52	High accuracy in-situ vertical profile measurements completed	WP3	7 - RUG	36	High accuracy in-situ vertical profile measurements completed

Partner: 7-RUG
Description of work carried out in T3.1 by beneficiary
Beneficiary 7-RUG contributed to Milestone MS52 by organizing the comparison program of the second intensive AirCore campaign in Trainou, France, in June 2019, with strong local supports by our Task 3.1 partner LSCE. Besides this, RUG continued to organize regular telecons to discuss the progress on processing the data obtained during the campaign.
Significant results:
Compared to the first intensive campaign in Sodankylä in June 2018, we have made two new achievements:

1. Tests of AirCore payloads that are below 3 kg, and a direct comparison of multiple flights that are launched one after the other;
2. Two new trace gas species N_2O (Picarro&Aerodyne) and COS (Aerodyne) measurements, in addition to CO_2, CH_4, CO

The tables below summarized the profile measurements analyzed by RUG during the RINGO Trainou campaign. In total, we've made two AirCore flights for CO_2, CH_4, CO profiles, four AirCore flights for COS, N_2O, CO_2, CH_4, CO, and one LISA flights for CO_2, CH_4, CO profiles.

Table 3.1 A summary of AirCore profiles during the RINGO Trainou campaign

Date	Flt#	Payload	Analyzer	Species	Comments
20190612	4	RUG AirCore	RUG Picarro G2401	CO_2, CH_4, CO	8 ppm CO as fill gas
20190617	10	RUG AirCore	LSCE Picarro G2401	CO_2, CH_4, CO	LSCE normal CO as fill gas
20190617	13	LMD/LSCE AirCore	RUG Aerodyne QCLS	COS, N_2O, CO_2, CH_4, CO	No AirCore dryer; Datalogger relative time only; Analyzed with a dryer;
20190618	16	RUG AirCore	RUG Aerodyne QCLS	COS, N_2O, CO_2, CH_4, CO	With AirCore dryer; Analyzed without a dryer;
20190618	18	LMD/LSCE AirCore	RUG Aerodyne QCLS	COS, N_2O, CO_2, CH_4, CO	No AirCore dryer; Data logger relative time only; no retrieval yet; Analyzed with a dryer;
20190620	22	RUG AirCore	RUG Aerodyne QCLS	COS, N_2O, CO_2, CH_4, CO	No AirCore dryer; Analyzed with a dryer;

Table 3.2. A summary of LISA profiles during the RINGO Trainou campaign

Date	Flt#	Payload	Analyzer	Species	Comments
20190617	11	RUG LISA 4 samples	LSCE Picarro G2401	CO_2, CH_4, CO, to be ^{13}C and ^{18}O in CO	
20190618	17	RUG LISA no samples	-	-	
20190620	23	RUG LISA 4 samples	LSCE G5310 + RUG G2401	N_2O, CO, CO_2, CH_4, CO, to be ^{13}C and ^{18}O in CO	

The Figure 10 below shows the AirCore profiles of COS, N_2O, CO_2, CH_4, CO from four different flights.

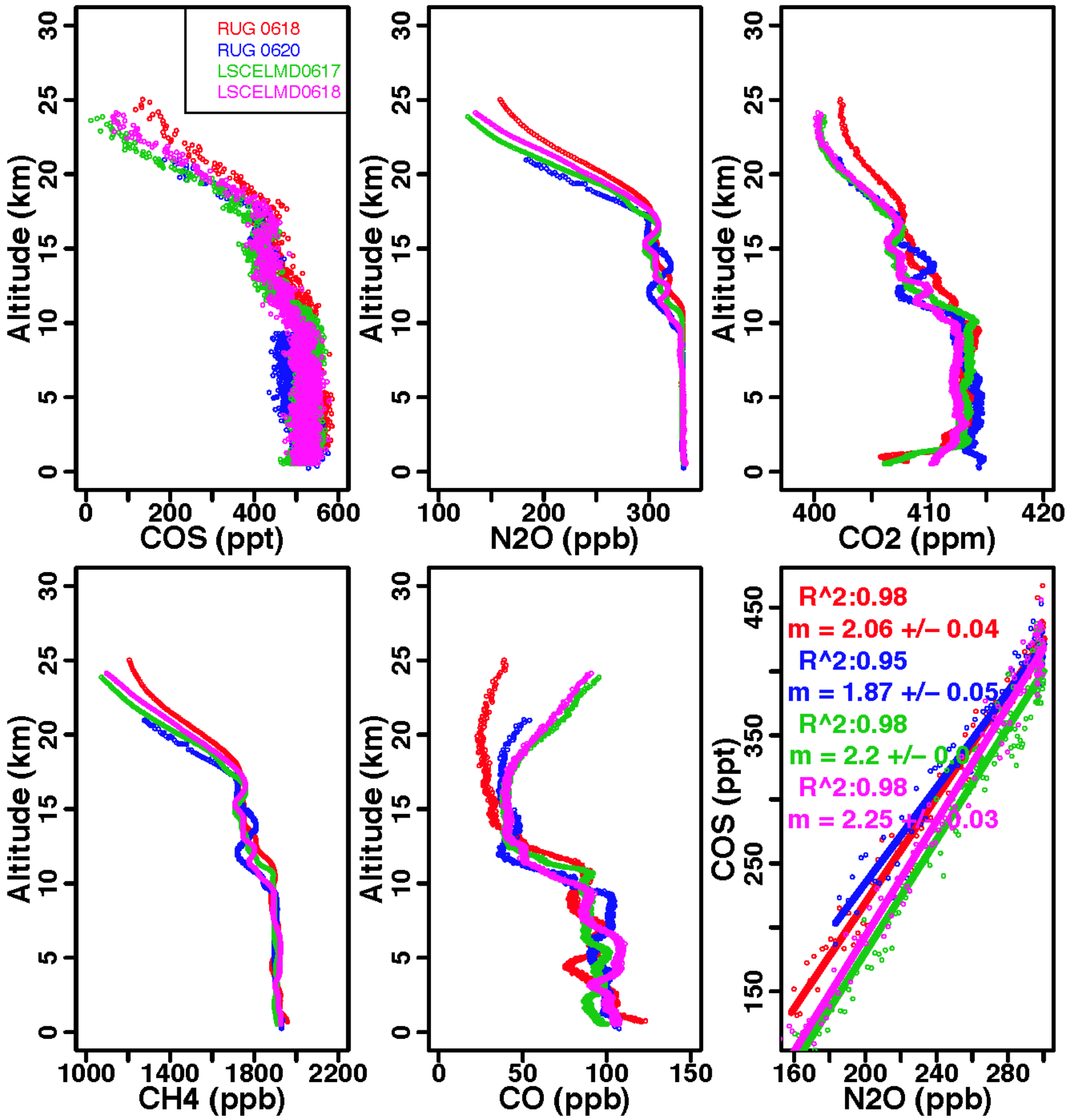

Figure 10. AirCore profiles of COS, N_2O, CO_2, CH_4, CO retrieved from four flights during the RINGO Trainou campaign, the last panel shows the tight correlation between COS and N_2O in the stratosphere

Partner: 4-UVSQ
Description of work carried out in T3.1 by beneficiary
Beneficiary 4-UVSQ contributed to Milestone MS52 by:
1. Organization of the second intensive AIRCORE measurement campaign in Trainou (France) between June 10-21, 2019.
2. Analysis of the French AIRCORE launched during the Trainou campaign.
Significant results:
Before hosting the measurement campaign in Trainou, a preparatory work included:
- administrative matters: request of the different authorizations to launch balloons in Trainou at military and civil aviation authorities,
- logistical matters: the establishment of a field laboratory to host 8 analyzers at the launching site, and accommodation booking,
- technical matters: order the whole material for the balloon launchings (balloons, parachutes, balloon tracking systems, helium gas to inflate the balloons).

7 institutes (20 participants) participated in the TRAINOU campaign (10-21st June 2019). In addition, we organized the coordination of the RINGO campaign with the MAGIC airborne campaign. An airplane flew over the TRAINOU tower on June, 18th with in-situ CO_2, CH_4 and CO measurements. As part of this collaboration, the GSMA institute (University of Reims, France) participated in the last day of the RINGO campaign with the AMULSE spectrometer for CO_2 and H_2O measurements, which made one balloon profile.
During the measurement campaign, we contributed by:
- preparing the flight chains for 27 balloons in total during 7 days (up to 6 balloons per day during 2 days) and organizing the retrieval of all of the AirCores. In overall 28 vertical profiles were measured.
- lauching 5 French AIRCORES to get vertical profiles of CO_2, CH_4, CO, and N_2O.
- providing calibration tanks to all participants.

After the campaign, we provided all the participants with the flight data, which are necessary for data processing.
The French AIRCORE data acquired during the first (June 2018 in Sodankylä, Finland) and second (June 2019 in Trainou, France) intensive measurement campaign contributed to the following presentations:

- Lopez, M., Ramonet, M., Kouassi, K., Laemmel, T., Bes, C., Hase, F., Warneke, T., Petri, C., Té, Y., Jeseck, P.& C. Crevoisier: Toward a better understanding of greenhouse gas atmospheric profiles around ICOS Trainou station – France. ICOS MSA Atmosphere Meeting (Bologna, Italy), November 2019.
- Chen, H., van Heuvan, S., Leuning S, Krol, M., Laemmel, T., Ramonet, M. & C. Crevoisier: AirCore Observations of COS and Other Greenhouse Gases. 2nd International COS workshop (Obergurgl University Center, Austria), November 2019.
- Laemmel, T., Lett, C., Kouassi, M., Lopez, M., Ramonet, M., Crevoisier, C., Danis, F., Pernin, J., Delmotte, M., Laurent, O., Rivier, L. & P. Ciais: Extended vertical profile measurements of greenhouse gases using the Aircore technique: the case of supersite Trainou, France. Annual Scientific and Technic Assembly of ICOS France (Roscoff, France), November 2019.
- Lopez, M., Ramonet, M., Bes, C., Hase, F., Kouassi, M., Laemmel, T., Té, Y., Jeseck, P., Warneke, T., Petri, C. & L. Rivier: Atmospheric column measurements of greenhouse gases by remote sensing techniques: from validation to intensive measurement campaigns. Annual Scientific and Technic Assembly of ICOS France (Roscoff, France), November 2019.

Figure 11. Preparatory phase for the simultaneous launching of three balloons at Trainou.

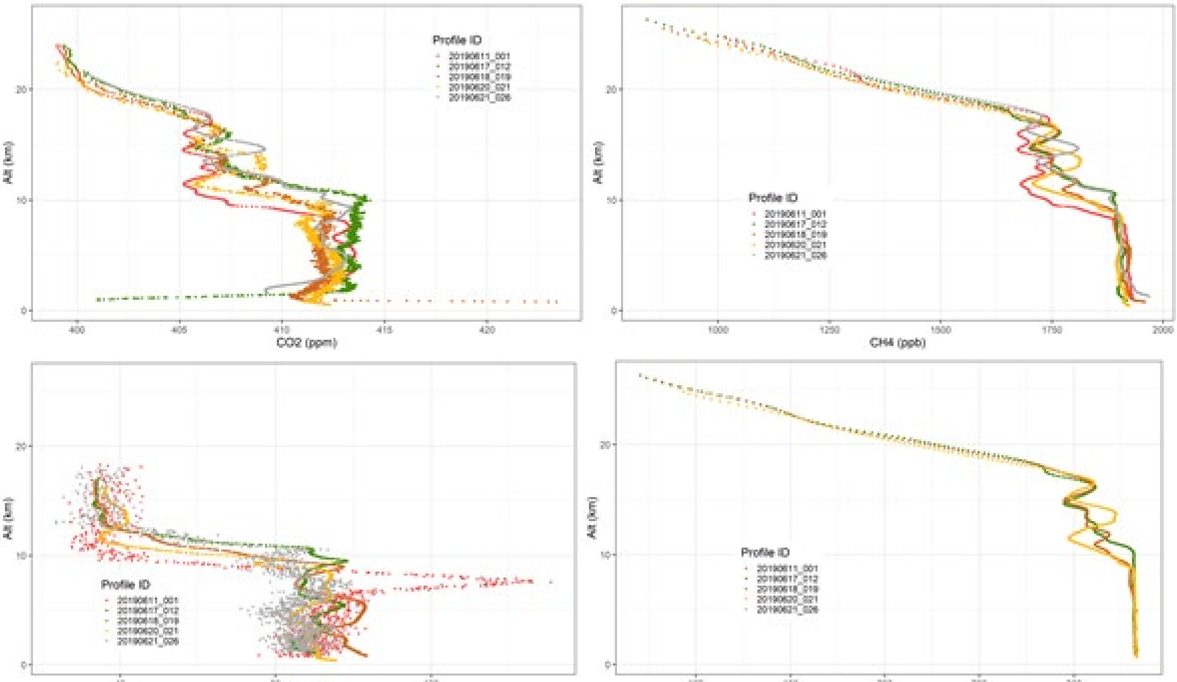

Figure 12. Vertical profiles of CO_2, CH_4, CO and N_2O measured by the 5 French AIRCORES during the intensive campaign in Trainou.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

During this RP2 more PM than initially foreseen by the DoA were declared, which is absorbed by the transfer of unspent funds from direct costs to personal costs and lower average costs of our technicians than initially foreseen.

Partner: 25-GUF

Description of work carried out in T3.1 by beneficiary

Beneficiary 25-GUF contributed to Milestone MS52 by deploying AirCore systems during both the campaigns in Sodankylä and in Trainou. While GUF also provided data for intercomparison of vertical profiles of CO2 and CH4 and participated in inter-calibrations, the main innovation brought forward by GUF was a new method to test the altitude attribution of AirCore profiles. In addition, a range of tests

on the University Frankfurt AirCores have been performed in preparation of the Trainou campaign (slug-test, stability tests and calibrations).
For the new altitude attribution testing method, small amounts of a gas with a high concentration of CO are released at pre-defined altitudes during the flight. This high concentration of CO can be clearly differentiated from ambient air. The altitude of the pulse release is known and can then be compared with the altitude to which the observed pulse is attributed in the AirCore retrieval. The system consists of a small micro-valve which can be pulsed very fast (10-50 ms pulses have been used here) to release small amounts of gas directly into the inlet of the AirCore. The system failed due to the cold temperature of the valve during the Sodankylä campaign. For the Trainou campaign, a small heater was added to the set-up, and it worked well with pulses being released at intervals between 3 and 5 km. Due to problems with the on-board data recording and the pressure values of the on-board radiosondes, the evaluation is still ongoing and will be finished within the next periodic reporting period. A publication on the results is foreseen.
The participation of GUF in the Trainou campaign was not foreseen in the initial work plan and must thus be considered an addition to the work proposed beforehand.

Significant results:
Development of a new method to test the altitude attribution of AirCore profiles.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions
In deviation of the original DoA, GUF participated in the AirCore campaign from Trainou. This addition was possible due to the partial use of internal funds.

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Partner: 24-UBremen
Description of work carried out in T3.1 by beneficiary
Beneficiary 24-UBremen contributed to Milestone MS52 by continuing the developing of a proxy retrieval for tropospheric XCH_4 from ground-based solar absorption FTIR spectra in the near IR spectral region, evaluating the developed proxy retrieval using AirCore data, contributing to the manuscript for optimal estimation profile retrieval (Zhou et al, 2019) led by BIRA and conducting solar absorption measurements at Orleans during the AirCore campaign in June 2019.
Significant results:
Below comparisons are between (tropospheric) column averaged mole fractions derived from solar absorption FTIR spectra in the near-IR. The proxy method for the retrieval of the tropospheric column averaged mole fraction of CH_4. Fig 14 and 15 show the dependence of the difference between AirCore and proxy retrieval on the tropopause altitude. The next steps will focus on understanding the difference and resolve the problem within the proxy retrieval.

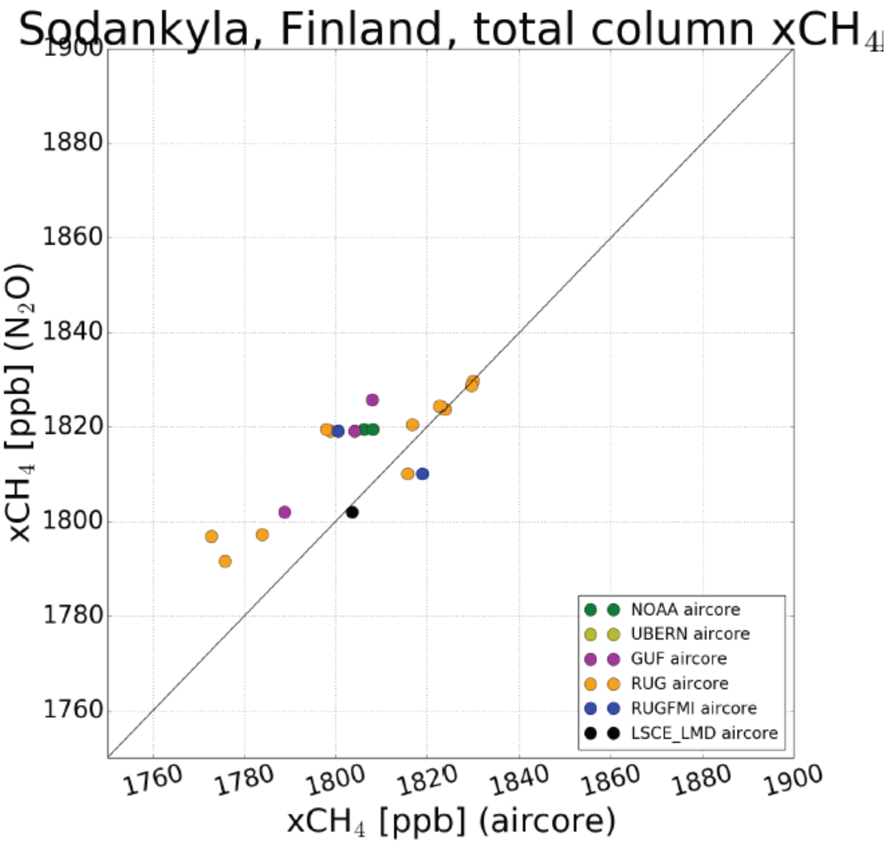

Figure 13 Comparison of the column averaged mole fractions of CH_4 from solar absorption FTIR spectra (vertical axis) and AirCore (horizontal axis).

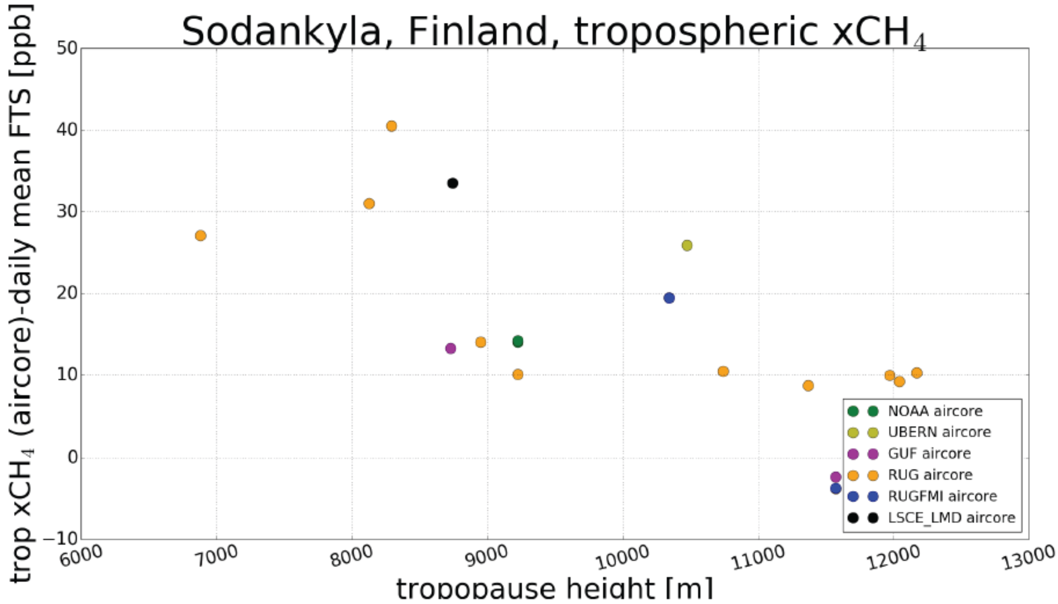

Figure 14 Difference between tropospheric column averaged mole fractions of CH_4 from AirCore and solar absorption FTIR spectra vs tropopause height at Sodankyla.

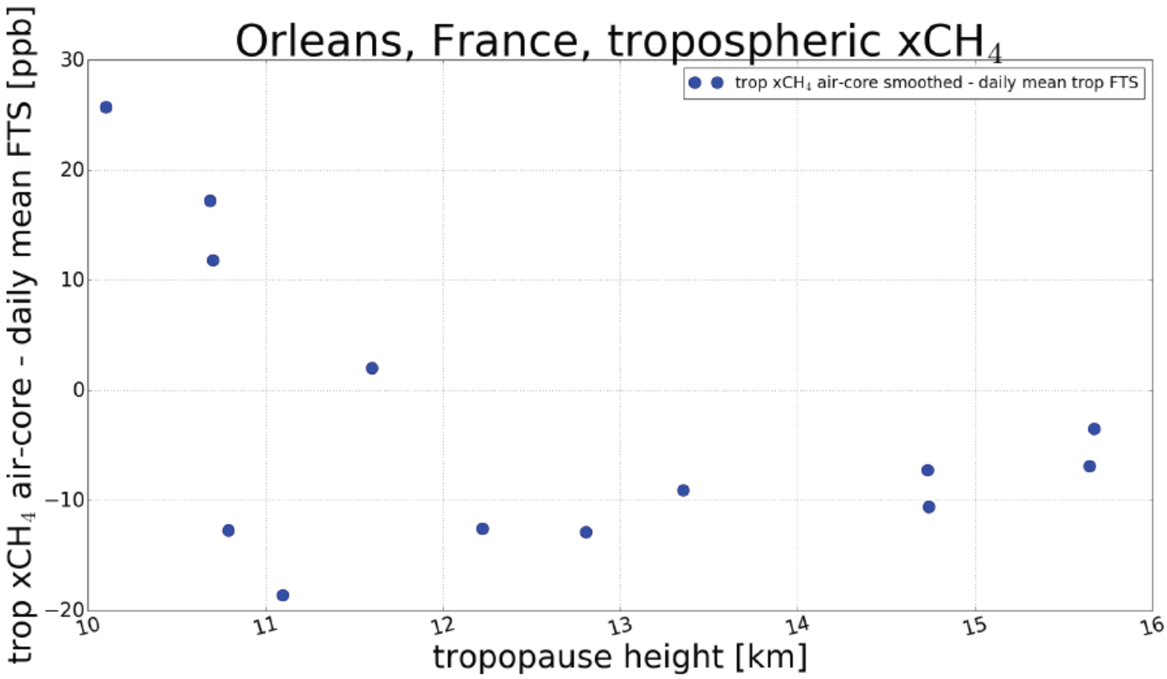

Figure 15. Difference between tropospheric column averaged mole fractions of CH_4 from AirCore and solar absorption FTIR spectra vs tropopause height at Orleans. The AirCore data does not include the campaign in June 2019.

Next steps:

- Implementation of the proxy retrieval in the upcoming retrieval package of the TCCON network (currently in the testing phase)
- Comparison of the proxy retrievals to AirCore measurements during the 2019 Orléans campaign.
- Applying the proxy retrieval to non-European sites where vertical resolved data is available
- Compare the optimal estimation method SFIT4NIR with the proxy method using N_2O and HF in collaboration with BIRA.

Partner: 9-UHELFMI

Description of work carried out in T3.1 by beneficiary

Beneficiary 9-UHELFMI contributed to Milestone MS52 by building a new AirCore instrument and by completing high accuracy in-situ vertical profile measurements. The light-weight instrument design was motivated by the need to fly an AirCore without a flight transponder. The AirCore payload included also a positioning device and a Modem radiosonde M10. A data logger and automatic valve was constructed prior to the flights. The temperature of the coil was measured at 6 points during the flight, in addition, ambient pressure was recorded by the data logger. The valve closing was programmed based on the pressure readings. The M10 radiosonde was provided by the local organiser as well as a meteorological balloon to lift the instrument to about 35 km of altitude in the stratosphere. Gas sampling was conducted during the balloon descent from the stratosphere down to the surface. Ground equipment, such as a gas analyser and calibration/filling gases for the AirCore preparation and sample analysis were provided by the University of Groningen at the campaign site. The instrument was flown during the campaign in Trainou, France side by side with other instruments by RINGO partners and by two additional groups being not part of the RINGO consortium. FMI participated in the field campaign in Traînou during 12-19 June 2019. In addition FMI, in collaboration with the University of Groningen, performed a series of AirCore flights near the Sodankylä TCCON and ICOS site, covering all seasons during the year 2019.

Significant results:

A new high-accuracy instrument was built, and vertical profile measurements were completed in the vicinity of the Traînou ICOS site. In addition, AirCore flights were performed near the Sodankylä TCCON and ICOS site.

FMI participated in the 3rd RINGO Annual meeting, March 20-22, 2019, Southampton, UK. FMI contributed to several publications.

Results were also presented at conferences:

Kivi R, Heikkinen P, Hatakka J, Laurila T, Lindqvist H, Chen H, Fourier Transform Spectrometer measurements of column CO_2 and CH_4 at Sodankylä, Geophysical Research Abstracts, Vol. 21, EGU2019-10520, 2019
Kivi R, Heikkinen P, Hatakka J, Laurila T, Lindqvist H, Tamminen J, Chen H, Remote Sensing Measurements of Methane and Carbon Dioxide at Sodankylä, Finland, 2019 Living Planet Symposium, 13-17 May 2019, Milan, Italy
Kivi R, Kujanpää J, Heikkinen P, Calbet X, Lindqvist H, Atmospheric Composition Measurements over Northern Finland. 2019 Joint Satellite Conference, 28 September - 4 October 2019, Westin Waterfront, Boston, MA
Kivi R, Heikkinen P, Laurila T, Chen H, Lindqvist H, Tamminen J, Greenhouse Gas Measurements at the Sodankylä TCCON Site and Comparisons with the Satellite Borne Observations, The 15th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-15), June 3rd - 5th, 2019, Hokkaido University, Sapporo, Japan, 2019
Kivi R, Heikkinen P, Kivimäki E, Putkiranta P, Hatakka J, Laurila, T., H. Chen, Sentinel-5P and ground based measurements of methane over Sodankylä, Finland. Copernicus Sentinel-5 Precursor Validation Team Workshop, 11-14 Nov. 2019, ESA/ESRIN, Frascati, Italy, 2019
Papers in 2019:
Zhou M, Langerock B, Sha M.K, Kumps N, Hermans C, Petri C, Warneke T, Chen H, Metzger J, Kivi R, Heikkinen P, Ramonet M, Mazière M.D, Retrieval of atmospheric CH_4 vertical information from ground-based FTS near-infrared spectra, Atmospheric Measurement Techniques Vol. 12 p. 6125-6141. https://www.atmos-meas-tech.net/12/6125/2019/ doi: 10.5194/amt-12-6125-2019, 2019.
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Schneising O, Buchwitz M, Reuter M, Bovensmann H, Burrows J.P, Borsdorff T, Deutscher N.M, Feist D.G, Griffith D.W, Hase F, Hermans C, Iraci L.T, Kivi R, Landgraf J, Morino I, Notholt J, Petri C, Pollard D.F, Roche S, Shiomi K, Strong K, Sussmann R, Velazco V.A, Warneke T, Wunch D, A scientific algorithm to simultaneously retrieve carbon monoxide and methane from TROPOMI onboard Sentinel-5 Precursor, Atmospheric Measurement Techniques Discussions Vol. 2019 p. 1-44. https://www.atmos-meas-tech-discuss.net/amt-2019-243/ doi: 10.5194/amt-2019-243, 2019.
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Wilzewski J.S, Roiger A, Strandgren J, Landgraf J, Feist D.G, Velazco V.A, Deutscher N.M, Morino I, Ohyama H, Té Y, Kivi R, Warneke T, Notholt J, Dubey M, Sussmann R, Rettinger M, Hase F, Shiomi K, Butz A, Spectral Sizing of a Coarse Spectral Resolution Satellite Sensor for XCO_2, Atmospheric Measurement Techniques Discussions Vol. 2019 p. 1-25. https://www.atmos-meas-tech-discuss.net/amt-2019-227/ , 2019.

Partner: 11-ETHZUBern

Description of work carried out in T3.1 by beneficiary

Beneficiary 11-ETHZUBern contributed to Milestone MS52 by performing laboratory tests in order to better quantify the AirCore profiles.

Significant results:

Laboratory tests done include: (1) Simulation of flights (pressure and flow control) to investigate mixing processes as well as diffusion and dispersion of sampled gases; (2) tests with a new low-volume valve that allows spiking for improved altitude assignments. In order to reach these goals, pressure, and flow controllers were used that were driven by a LabVIEW Program parametrized to mirror a real flight profile obtained during the Sodankylä campaign in Northern Finland in 2018. This allowed to test the filling and decanting processes and fractionations associated with these procedures. We presently work on a publication summarizing these results. Regarding the second goal, we contacted a Swiss company producing small-volume valves that can be triggered with high frequency to release small gas amounts. This is an ideal situation of spike the sampled gas at certain GPS triggered altitudes that allows to improve the altitude assignments. This is particularly important for stratospheric samples where the descending velocity due to the low gas pressure. The tests performed were very successful, and we hoped to get nice results during the Ringo campaign in Trainou, France, 2019. Yet, experiences were different because we found a problem with the cold temperatures at high altitudes where the valve get partly blocked and did not release the expected amount of gas despite the correct triggering of the valve by the LabVIEW program. Meanwhile, we have redesigned the valve by adding a heater. The first results in a cold room were successful.

The campaign in Trainou, organized by our French colleagues from the „Laboratoire des sciences du climat et de l'environnement"(LSCE), Saclay France, with the participation of several international groups from the Netherland, Finland, Great Britain, France, Germany, Switzerland, and the United States, was focusing again on a comparison program that has been started last year in Sodankylä.

We used the same setup as 2018 with two Picarro instruments in series. Unfortunately, the first UBern flight was not successful since the connection from the AirCore to the parachute broke, and the AirCore was descending in free fall. It reached the ground with rather high speed but luckily did not lead to serious damage. After 24 hours, it was found and measured for its air composition. After repair by our technician, the AirCore could be flown again during the remaining time additional two times.

The partner of tasks 3.1 were organized and discussed issues related to the campaign through four teleconferences.

Partner: 26-BIRA

Description of work carried out in T3.1 by beneficiary

Beneficiary 26-BIRA contributed to Milestone MS52 by establishing a fully-physical CH_4 profile retrieval method for ground-based FTIR near-infrared spectra.

Significant results:

In order to obtain several vertical pieces of information in addition to the total column, the SFIT4 retrieval code is applied to retrieve the CH_4 mole fraction vertical profile from the Fourier transform spectrometer (FTS) near-infrared spectra at Ny-Ålesund, Sodankylä, Bialystok, Bremen, Orléans, and St-Denis. The retrieval strategy of the CH_4 profile retrieval from ground-based FTS near-infrared (NIR) spectra using the SFIT4 code (SFIT4NIR) has been investigated. The significant results are:

- Fix the retrieval strategy, e.g. spectroscopy, spectral windows, a priori profile, regularization.
- The degree of freedom for signal (DOFS) of the SFIT4NIR retrieval is about 2.4, with two distinct pieces of information in the troposphere and in the stratosphere.
- Estimate the retrieved profile uncertainty based on the optimal estimation, including the smoothing error, the model parameter error, and the measurement error.
- The CH_4 seasonal variations in the troposphere and stratosphere observed by in situ measurements and ACE-FTS satellite measurements are well captured by the SFIT4NIR retrievals.

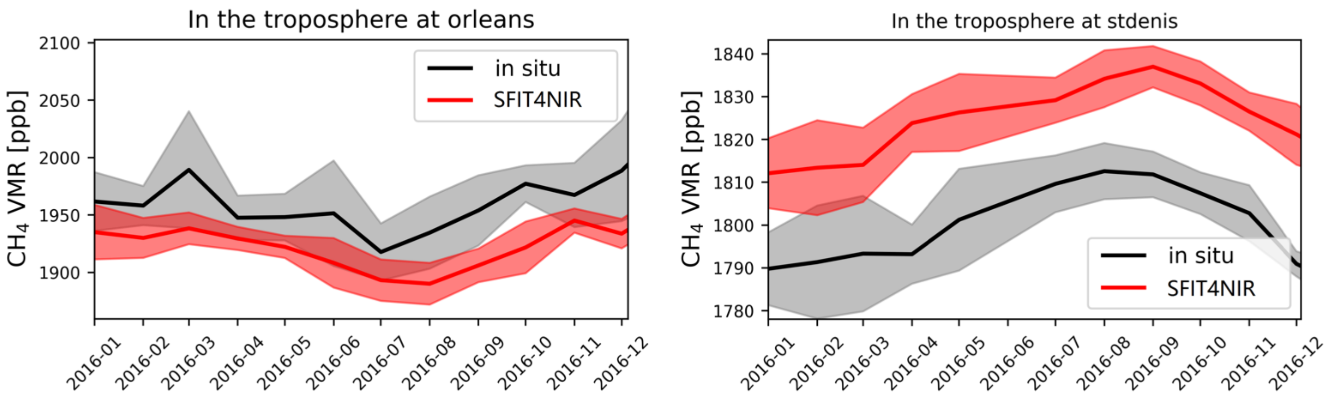


Figure 16 The time series of the monthly means (solid line) and standard deviations (shading) from the SFIT4NIR tropospheric XCH_4 and the ground-based in situ CH_4 measurements at Orléans (a) and at St Denis (b). At Orléans, the in situ measurements are recorded at 180m on a tower at the same place. The in situ measurements at St Denis are recorded at 2155m on Maïdo mountain, which is about 20km away from St Denis.

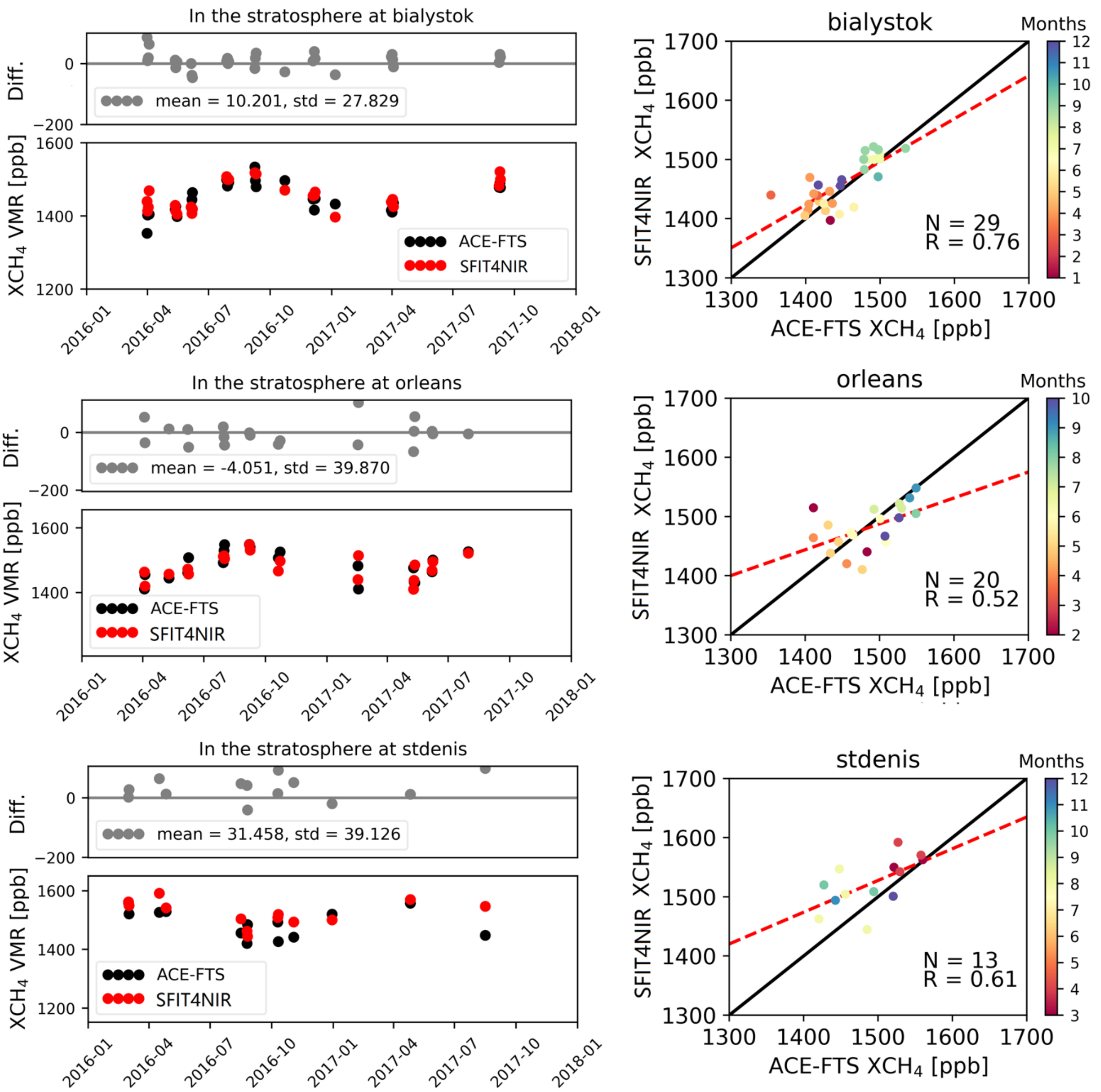


Figure 17. Left panels: the time series of the daily mean of the co-located SFIT4NIR and ACE-FTS stratospheric XCH_4 daily mean measurements, together with the absolute differences (unit: ppb) between them for Bialystok, Orléans and St Denis. Right panels: the correlation plots between the co-located SFIT4NIR and the ACE-FTS stratospheric XCH_4 daily means.

- Evaluate the SFIT4NIR total column uncertainty by comparison with the standard TCCON products: We found that the retrieval uncertainty of SFIT4NIR XCH_4 is similar to that of TCCON standard retrievals with systematic uncertainty within 0.35% and random uncertainty of about 0.5%.

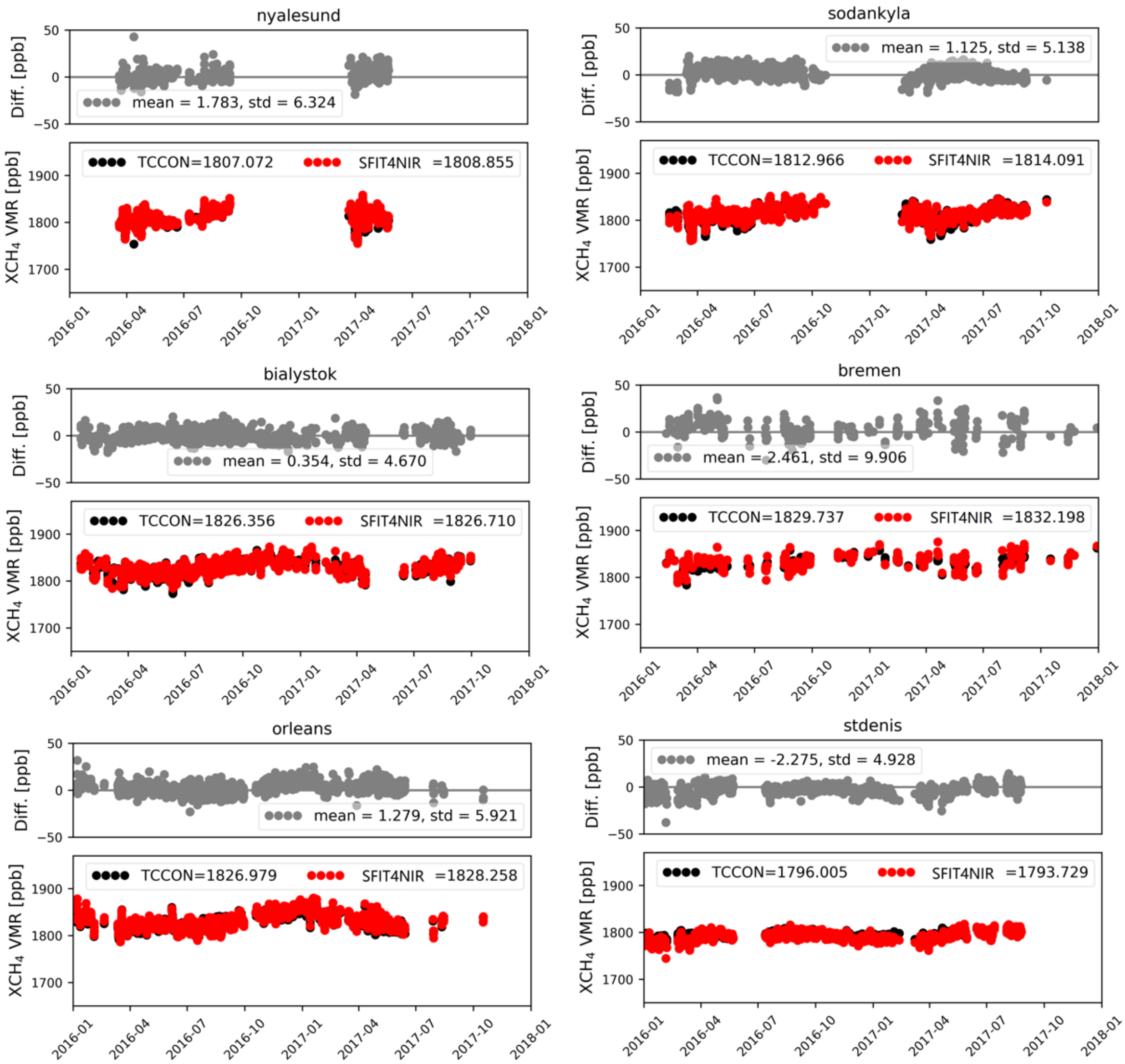


Figure 18. The time series of hourly means of $XCH_4$from the SFIT4NIR and the TCCON retrievals at six TCCON sites during 2016–2017, together with their differences. For each site, the lower panel shows the time series of SFIT4NIR and TCCON measurements, and the upper panel shows the absolute difference between them (SFIT4NIR–TCCON; in ppb units). The values in the legend of the lower panel are the means of the TCCON and SFIT4NIR retrievals.

- Evaluate the SFIT4NIR tropospheric and stratospheric columns uncertainties by comparison with AirCore measurements at Sodankyläand IMECC (infrastructure for Measurement of the European Carbon Cycle) aircraft measurements at Bremen, Bialystok and Orléans: it is found that there is a 1.0±0.3% overestimation in the SFIT4NIR tropospheric XCH_4 and a 4.0±2.0% underestimation in the SFIT4NIR stratospheric XCH_4.

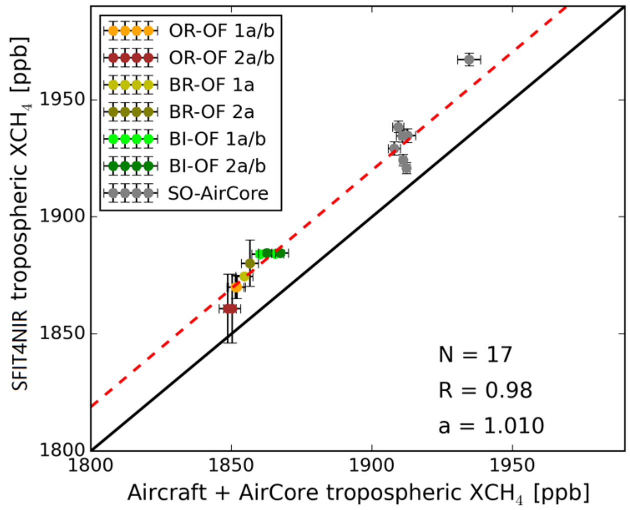


Figure 19. The scatter plots of XCH_4 between the SFIT4NIR and the IMECC aircraft measurements together with the AirCore measurements for the tropospheric components. The black line is the one-to-one line and the dashed red line is the regression line with the intercept to zero (y =a · x). N is the co-located measurement number, R is the correlation coefficient and a is the slope.

- Compare the SFIT4NIR retrieval with AirCore measurements during the Sodankylä 2018 RINGO campaign from 6 groups: GUF (Goethe University Frankfurt), LMD (Le Laboratoire de Météorologie Dynamique), NOAA (National Oceanic and Atmospheric Administration), LSCE (Laboratoire des sciences du climat et de l'environnement), UBern (University of Bern) and RUGFMI (University of Groningen,Finnish Meteorological Institute). As an example, Figure 3.11 shows the comparison between the SFIT4NIR retrievals and three AirCore measurements from GUF, LMD and NOAA on 21 June 2018.

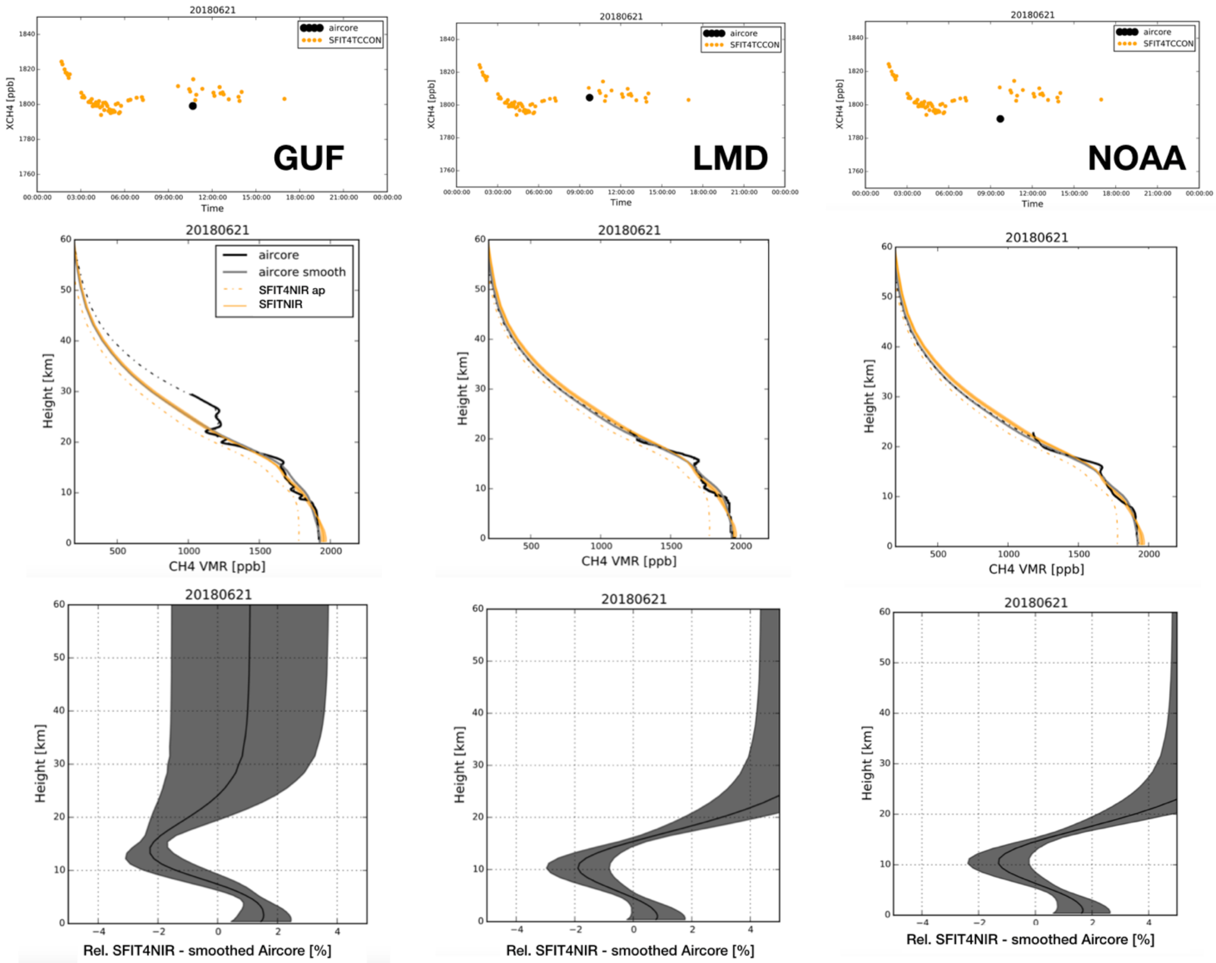


Figure 20. The comparison between the SFIT4NIR retrievals with three AirCore measurements from GUF, LMD and NOAA on 21 June 2018 during the RINGO campaign at Sodankylä. The upper panels are the SFIT4NIR retrieved XCH_4 together with the AirCore XCH_4. The middle panels are the SFIT4NIR a priori and retrieved profiles and AirCore profile (with and without smoothing). The lower panels are the relative differences between SFIT4NIR retrieved profile and smoothed AirCore profile.

- Provide support to the Orléans by looking at the satellite data: We have looked at the Sentinel-5 Precursor (S-5P) satellite overpass data during the campaign period and provided plots for the specific campaign days. We have also provided the timeseries of the S-5P methane and carbon monoxide total column products around the Orléans TCCON site. This AirCore data from the campaign will be used for the validation of the S-5P data.

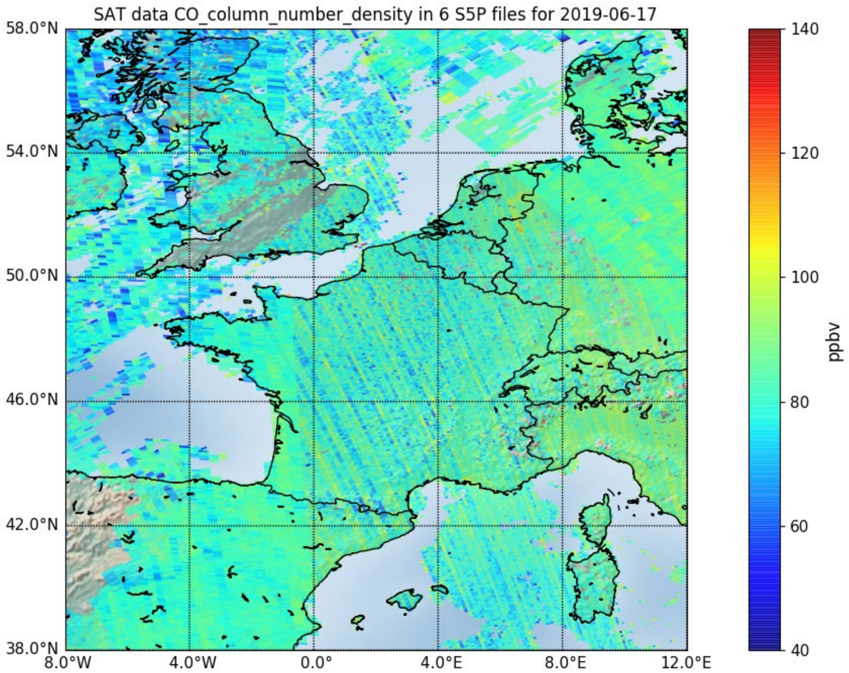


Figure 21. XCO plotted from S-5P orbit overpasses for ± 10 degrees around Orléans TCCON site.

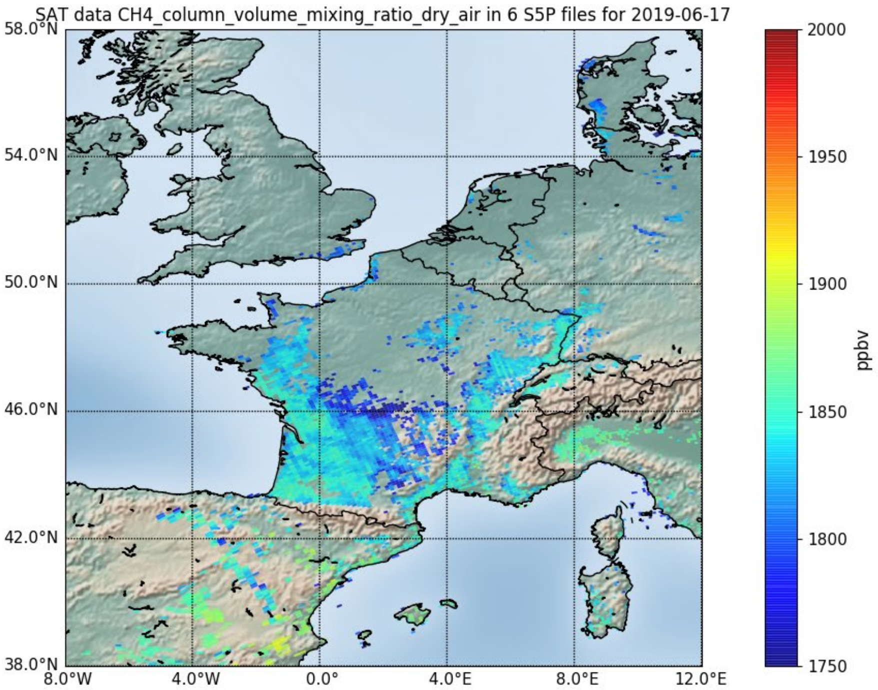
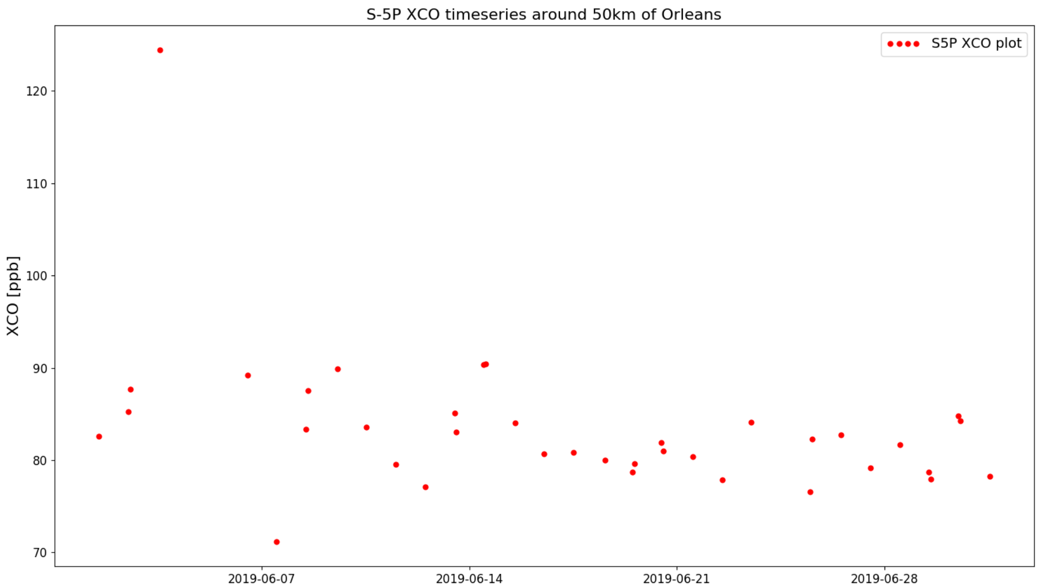


Figure 22. XCH_4 plotted from S-5P orbit overpasses for ± 10 degrees around Orléans TCCON site.



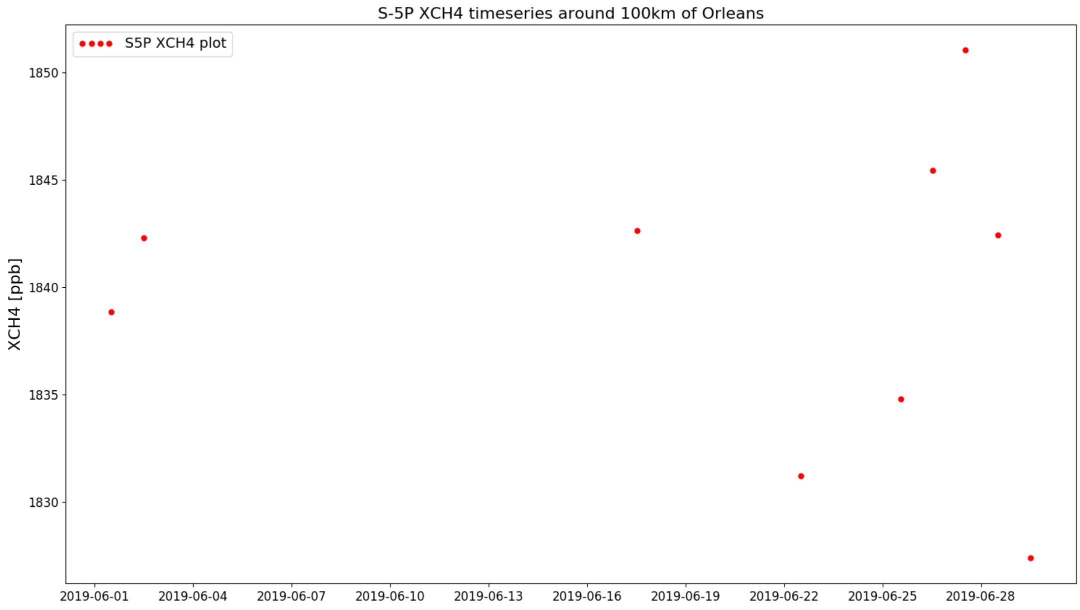


Figure 23. Timeseries of XCO (top panel) and XCH_4 (bottom panel) from S-5P with co-incidence criterion of 50km and 100km radius around Orléans TCCON site, respectively.

One peer-reviewed paper has been published:

- Zhou, M., Langerock, B., Sha, M. K., Kumps, N., Hermans, C., Petri, C., Warneke, T., Chen, H., Metzger, J.-M., Kivi, R., Heikkinen, P., Ramonet, M., and De Mazière, M.: Retrieval of atmospheric CH_4 vertical information from ground-based FTS near-infrared spectra, Atmos. Meas. Tech., 12, 6125–6141, https://doi.org/10.5194/amt-12-6125-2019, 2019.

Next steps:

- The SFIT4NIR retrievals will be applied to compare with the AirCore measurements launched during the 2019 Orléans campaign.
- Apply the SFIT4NIR retrieval to more TCCON sites, especially where AirCore or aircraft measurements are available.
- Collect more AirCore and aircraft measurements and use them to validate the SFIT4NIR retrievals.
- Compare the SFIT4NIR CH_4 tropospheric and stratospheric columns with the proxy method using N_2O.

Task 3.2: Improving atmosphere measurements on voluntary observing ships

Task leader: IOW (9); Participants: ICOS ERIC (2), UVSQ (10), UHEIMPI-BGC (4), GEOMAR (8)

List of deliverables due to be completed within this task within this reporting period:
D3.2 Report on implementation and technical realization of atmospheric measurements on the three VOS platforms (M20)
Due to several reasons, this Deliverable Report had to be postponed and was not finalized within the reporting period. These circumstances include:
for IOW - late solution to the administrative status which let to the amendment in which IOW became additional beneficiary (month 7 of the project); (b) late delivery of the Picarro instrument needed for construction (M14); need to find a new ship for the installation due to an unforeseen decline by the ship line despite earlier negotiations. Construction could not be started before a new ship was secured. More details in the beneficiary report.

For GEOMAR -since the SOOP Atlantic Cartier went out of service in 2017, it was agreed to move the scientific equipment to the newly build ATLANTIC SAIL operating on the same line. Due to lack of funding and the fact that only port calls of several hours could be used, the new installation took several months. The system was operational in February 2019, but after one successful crossing of the Atlantic, the ship went to the shipyard from March until November 2019.
for UVSQ - despite the delay, partner UVSQ finalized the installation, including several upgrades within the reporting period, though at a very late stage.

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS44	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms	WP3	27 –IOW	30	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms

Partner: 27- IOW

Description of work carried out in T3.2 by beneficiary

The main role of IOW in Task 3.2. is the construction and installation of a system allowing atmospheric CO_2 and CH_4 measurements on a VOS through the Baltic Sea.

Significant results:

The SOOP Tavastland, running between Lübeck and Umea, was identified as a very interesting option for the installation of the ATC-conform measurement system on a SOOP in the Baltic Sea after the installation on SOOP Finnmaid was not granted (see Deviations from DoW below).SOOP Tavastland is a designated ICOS contribution of Sweden by now, well accessible, and actually more interesting than the original SOOP Finnmaid (Lübeck - Helsinki) with respect to covering different Northern European air masses. Green light for the installation was granted in February 2019 (month 26 of the project). Due to individual ship safety regulations and spatial situation, assembly of the instrumentation could not start before that date. By now, following the ICOS atm. station specifications (Laurent 2014), and with continuous support from members of the ATC community, all components were assembled into a 19`rack, and a calibration gas unit was constructed. The atm. station is also already assembled. We expect first run on the vessel within the first quarter of 2020. IOW contributed to the white paper of Wanninkhof et a. (2019), which was published in the framework of the 2019 Oceanobs conference in Hawaii/USA.

	
Currently assembled system (left) and electronic unit / time server) of the system designed for SOOP Tavastland	Room plan of Ringo Task 3.2 installation on SOOP Tavastland, confirmed by the master of the ship

As a related activity, partners 23 and 27 contributed to a peer-reviewed publication on a network for surface ocean pCO_2 and marine boundary layer atmospheric CO_2 measurements (Wanninkhof et al., 2019).

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

As outlined in the first periodic report, the start of construction was delayed because of late entering as a beneficiary into the project and late availability of the sensor. Most importantly, however, the unforeseen decision of the shipping company (Finnlines) not to allow the installation on SOOP Finnmaid, despite earlier positive evaluation and the fact that IOW maintains pCO_2 installation on this ship since 2003, now as part of ICOS, lead to the necessity to find a new ship of operation. This problem was solved, see above (Significant Results). The deviations from the original planning is limited to the time line towards fulfilling the deliverables/milestones. No change in the use of resources. We think, with the actions taken, a very reasonable solution is found, matching perfectly the scope within the development of ICOS.

Partner: 1-ICOS ERIC

Description of work carried out in T3.2 by beneficiary

Beneficiary 1-ICOS ERIC was responsible for the procurement of the Picarro G2401 sensor to be used in the setUp of partner IOW, and also for technical knowledge transfer concerning atmospheric measurements matching ICOS ATC standards in general.

Significant results:

The main task for ICOS ERIC was the procurement of the Picarro G2401 realized within the first WP. There were no further obligations within the 2nd working period.

Partner: 4-UVSQ

Description of work carried out in T3.2 by beneficiary

As explained in the last reprint period, the installation of the instrument on board the Colibri vessel was delayed due to longer administrative and legal procedures than expected. A final agreement has been signed with the "Compagnie Maritime Nantaise" beginning of March 2019. The installation of the analyzer with its calibration scale was done on the second half of March 2019. The G2401 analyzer, enabling continuous measurement of CO_2, CH_4, CO, and H_2O, has been installed into a rack together with a multi-position valve and a full set of 4 quality control cylinders provided by the ICOS Calibration Center in Jena. In addition, a UPS device and an external hard disk have been added in order to secure the instrument and the data acquisition. All the devices have been installed on the third deck of the boat (Figure 24).

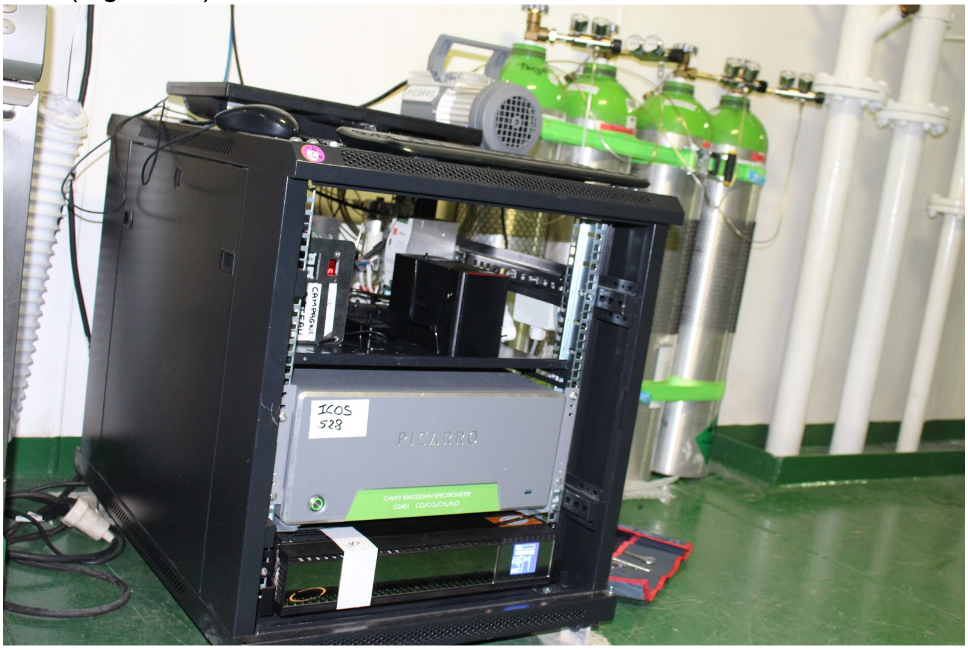


Figure 24. Photo of the instrumental set up on the Colibri Vessel.

The inlet line has been installed on top of the mast in front of the boat (ahead from the engine chimney), and a dedicated GPS system has also been installed on the main deck (Figure 25). Additional meteorological information will be provided by Météo France, which owned a full set of meteorological sensors onboard (temperature, pressure, relative humidity, and wind speed and direction).

Figure 25. View of air inlet (2a and 2b) and GPS sensor (2c)

Data acquisition has been starting from 19 March 2019. The first two months the Colibri vessel was quayside, which enable us to test our instrumentation setting, resulting in a first upgrade of the GPS acquisition system interface that was done in May 2019. In June 2019, the Colibri Vessel started his first transAtlantic cruise, followed by a second one in late August, beginning September. A first data recovery was done in mid-September, showing that the full set up was running well.

In November 2019, an automatic data transfer system (enabled when the boat reaches a harbour) has been implemented as well as a second upgrade of the GPS acquisition system (now decoupled from the Picarro acquisition system). With this new system, we are also able to connect and pilot the instrument while the vessel is at the quay. A third transatlantic cruise has been made end of November 2019. The next one is scheduled to start on January 23rd, 2020.

Since the end of March 2019, the monitoring system has then been running continuously, except during about a dozen days when the boat was in Gibraltar for heavy maintenance (end of September) where we were asked to stop the instrument for safety reason. Since September 2019, the data from the Colibri vessel are integrated and processed in the ICOS database. Figure 26 shows the time series of daily injections of one target gases showing the reproducibility of the measurements. Figure 27 shows the first measurements for the period from May to September 2019.

Beneficiary 4-UVSQ contributed to D3.2. by implementing an automatic and autonomous atmospheric greenhouse gases monitoring setup into the voluntary ship Colibri.

Beneficiary 4-UVSQ contributed to Milestone MS29 by completing the instrumental setup of the atmospheric monitoring device onboard the Colibri vessel and collecting the first data during the three transAtlantic cruises made between June and December 2019.

Significant results:

Installation, tests of the experimental setup was realized, and first data acquisition on a routine mode were obtained successfully.

At present day, the instrument has been running continuously, and three trans-Atlantic transects have been realized (Figure 27), providing data that have been processed in the ICOS database.

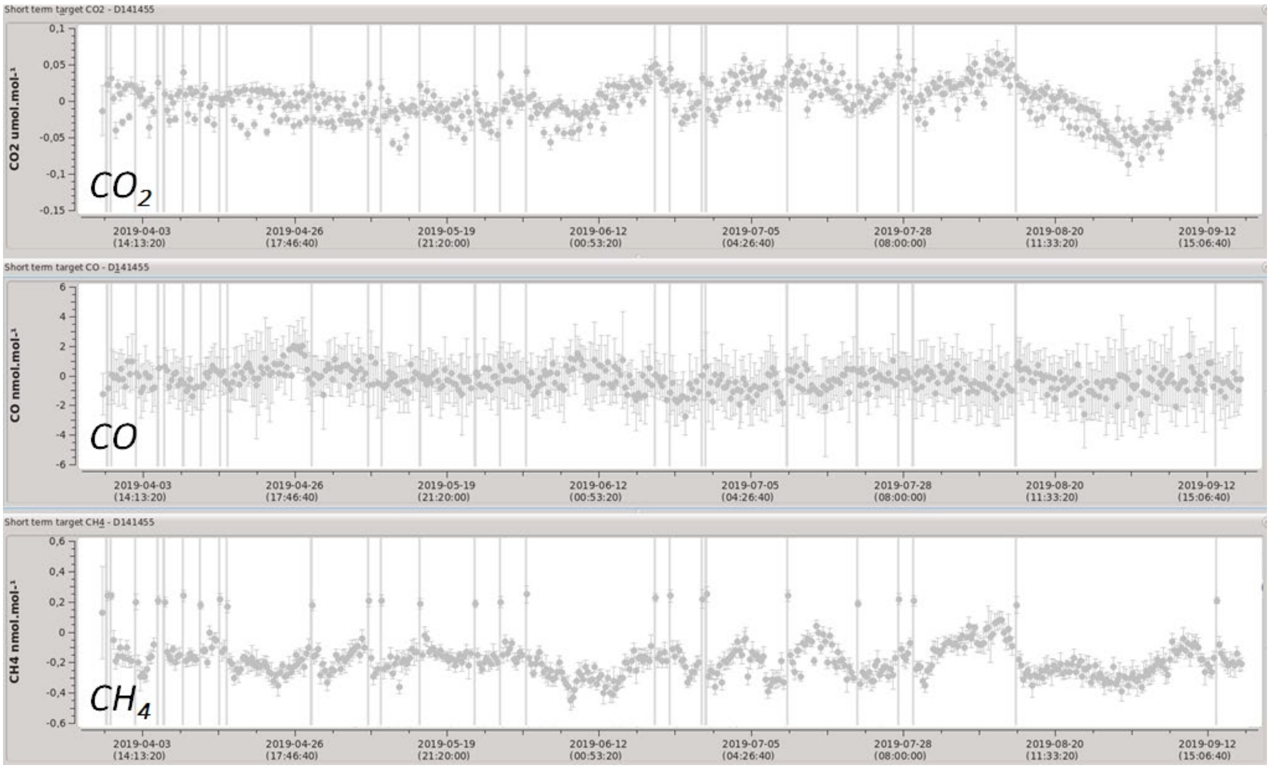


Figure 26 Time series of daily injections of one target gases showing the reproducibility of the measurements.

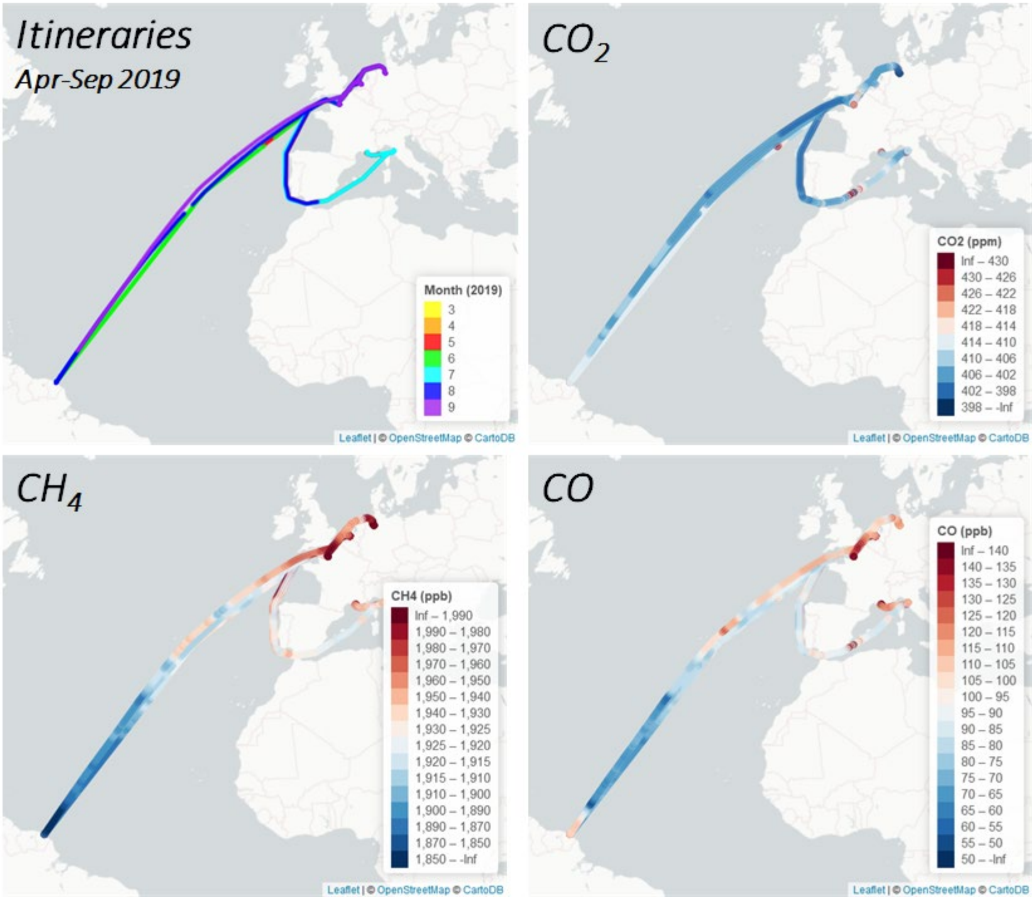


Figure 27 Cruises trajectories followed by the Colibri Vessel between March and September 2019, with corresponding CO_2, CH_4 and CO measurements.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

As outlined in the first periodic report, the start of construction was delayed because of late entering as a beneficiary into the project and late availability of the sensor. Most importantly, however, the unforeseen decision of the shipping company (Finnlines) not to allow the installation on SOOP

Finnmaid, despite earlier positive evaluation and the fact that IOW maintains pCO2 installation on this ship since 2003, now as part of ICOS, lead to the necessity to find a new ship of operation. This problem was solved, see above (Significant Results). The deviations from the original planning is limited to the time line towards fulfilling the deliverables/milestones. No change in the use of resources.

Partner: 5-UHEIMPI-BGC
Partner 5 role in the task is to provide the calibration gases for the onboard installation of the systems on SOOPs COLIBRI, TAVASTLAND, and ATLANTIC CARRIER, and to measure a number of flask samples after installation onboard TAVASTLAND and ATLANTIC CARRIER.
Significant results:
The gases to partners 4, 23 and 27 were already distributed within reporting period 1. The provision of a mobile flask sampler and measurement of flasks for QC will fall into the final reporting period. There were thus no actions/duties of partner 5 within the reporting period.

Partner: 23-GEOMAR
Description of work carried out in T3.2 by beneficiary
In summer 2018, the installations for a new pCO_2 measuring equipment onboard the ATLANTIC SAIL started. A commercially available so-called GO-system (General Oceanics, Miami, USA) was installed in the engine room of the vessel next to the seawater intake. In addition, ca. 80 m of tubing were installed to the top of the ship to regularly (every 3 hours for 10 minutes) measure the CO_2 content of the outside air. We installed and improved inlet filters that prevent salt getting sucked into the air line. This improved the measurement noise by a factor of 2 (±0.1 ppm CO_2). We also installed a buffer tank with 10 L volume before the instrument, but it turned out that this has not a significant effect on the measurements. All work on board could only be done during the ship's port calls in Hamburg, and the installation was finished in February 2019. The ship went to dry dock from March to November 2019.

In summer 2019, GEOMAR was able to use a new developed CO_2 sensor (LI7815, Licor Inc./USA) for testing. The software of the used equipment on board was adjusted to read the sensors output, and several tests were performed to test the sensors suitability for an installation on board. The sensor is measuring CO_2 with a higher accuracy than the sensor in use (LI7000, Licos Inc./USA) but is easy to implement at the same time. In November 2019, GEOMAR purchased a new CO_2 sensor (LI7815), which is planned to be installed on board early 2020.
Significant results:
Successfully moved the whole scientific installation to a new ship. Test runs of the newly developed CO_2 sensor (LI7815, Licor Inc./USA) showed that the sensor is suitable for ship board installations and will improve the uncertainty of atmospheric measurements on board SOOP lines. GEOMAR contributed to the white paper of Wanninkhof et a. (2019), which was published in the framework of the 2019 Oceanobs conference in Hawaii/USA.
Wanninkhof R, Pickers PA,Omar AM, Sutton A, Murata A, Olsen A, Stephens BB, Tilbrook B, Munro D, Pierrot D, Rehder G, Santana-Casiano JM, Müller JD, Trinanes J, Tedesco K, O'Brien K, Currie K, Barbero L, Telszewski M, Hoppema M, Ishii M, González-Dávila M, Bates NR, Metzl N, Suntharalingam P, Feely RA, Nakaoka S-i, Lauvset SK, Takahashi T, Steinhoff T and Schuster U (2019) A Surface Ocean CO_2 Reference Network, SOCONET and Associated Marine Boundary Layer CO_2 Measurements. Front. Mar. Sci. 6:400. , doi: 10.3389/fmars.2019.00400.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions
Due to the delay in installing the whole measuring system on board the new ship, no data were produced in the reporting period.

Task 3.3: Moving towards an autonomous system to measure ocean surface carbon uptake in regions and seasons where merchant vessel- based systems are not suitable

Task leader: NERCUoE (8)

List of deliverables due to be completed within this task within this reporting period:
D3.4 : Technological handbook and assessment report on CO_2-ASV. [36]
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS44	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms	WP3	23 – GEOMAR	30	Report on implementation and technical realization of atmospheric measurements on the three VOS platforms
MS53	Technological Handbook and Assessment Report on CO_2-ASV		23 – GEOMAR	36	Technological Handbook and Assessment Report on CO_2-ASV

Partner: 8-NERCUoE:
Description of work carried out in T3.3 by beneficiary
During this period, NERCUoE built, lab- and field-tested a self-contained, low power and volume instrument for accurate measurement of air and surface water pCO_2, suitable for integration into an ASV. The instrument consists of (1) LI-840A NDIR dector; (2) manifold and pump using latching micro valves, (3) electronics using an in-house single board computer for onboard logging of data with a custom made input/output board allowing the interfacing of modules, (4) gas standards contained in three microcan 200bar cylinders holding calibrated air with CO_2 concentrations of typically 300, 400, 500ppm, (4) a gas dryer made of a coil of Nafion tubing encased in Drierite desiccant, (5) air-water "H-shaped" equilibrator and (6) airblock which samples the atmosphere via a waterproof membrane. The instrument has been extensively lab tested.
The instrument has been field-tested on the River Exe using a towed body, performing satisfactorily.

Beneficiary 8-NERCUoE contributed to D3.4. by building and testing the instrument, but there is a delay to D 3.4, see below.
Significant results:
The instrument performs within spec so far, with suitably low power, weight and volume parameters that indicated it can be successfully mounted into an ASV for lengthy deployments.
Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions
There is a substantial and unavoidable delay to the incorporation and testing of the instrument in an ASV. Our instrument was designed for "Autonaut" ASVs, and the plan for this work was that we would test using the Autonaut vessel owned by NERC-NOC, however, we were informed by NOC after beginning RINGO, that this vessel would not be available due to technical problems. NOC has instead offered their "waveglider" ASV, however, this has a much smaller payload entailing re-design of the instrument. It is also unsuited to near-shore or shallow water deployments because of the substantial sub-surface component tethered below the surface body. The integration of our instrument into the waveglider is planned for March 2020, after which it will be possible to deliver D 3.4.

Task 3.4 Making non-CO_2 - GHG eddy covariance measurements operational

Task leader: UHEL (8) ; Participants: UNITUS (4), DWD (7), ETH (2); NERCCEH (6); DTU (5)

List of deliverables due to be completed within this task within this reporting period:
D3.5: Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling. [36] Protocol for eddy covariance measurements of CH_4 and N_2O fluxes, QA/QC, data processing and gap-filling (Month 36)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS54	Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling completed	WP3	9 - UHEL	36	Protocol for non-CO_2 eddy covariance measurements, QA/QC, data processing and gap-filling completed

Partner: 9-UHEL

Description of work carried out in T3.4 by beneficiary

Beneficiary 9-UHEL contributed to D3.5 and Milestone MS54 by coordinating the activities related to this Task. A dedicated workshop was organized on 19-20 March 2019 during the 3rd RINGO Annual meeting in Southampton. Several aspects related to CH_4 and N_2O eddy-covariance measurements are investigated. They focus both on setup and data processing, and they are: CH_4/N_2O data acquisition and synchronization, overflow inlet test, rawdata despiking, time lag adjustment, frequency response correction methods, ustar filtering and gap-filling. Currently, the writing of a Report "Protocol on non-CO_2 eddy-covariance measurements, QA/QC, data processing and gap-filling" is in progress, and the deliverable will be submitted on month 42, as agreed with the Coordinator.

We have established a collaboration with Sara Knox (British Columbia University), coordinating a recent Global Carbon Project methane budget activity aiming to the collection and aggregation of global CH_4 data from the flux tower community in coordination with the regional networks and FLUXNET initiatives. In particular, the collaboration focuses on machine learning tools for gap-filling flux data. A peer-review paper was recently accepted in BAMS (doi.org/10.1175/BAMS-D-18-0268.1).

Significant results:

Within this task, the Beneficiary 9-UHEL has focused, in particular, on the usage of different frequency response correction approaches for CH_4 fluxes and their impact on annual budgets. Data from Siikaneva wetland ICOS Station are used. In particular, power spectra approach (PSA) and cospectra approach (CSA) have been used to estimate the low-pass filter time constants of the EC system. The performance of these approaches is investigated for different attenuation conditions and signal-to-noise ratios.

A manuscript has been drafted, which will be submitted to Atmospheric Measurement Techniques (AMT) in February 2020.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The Deliverable 3.5 is in progress. Field tests and data analysis related to new processing methods have been recently finalized by the involved partners. The final report will be submitted in June 2020.

Partner: 3-UNITUS

Description of work carried out in T3.4 by beneficiary:

UNITUS, during the last reporting period, built the database for the halfhoruly CH_4 eddy covariance fluxes hosting also sites not in Europe (becoming a reference point). Currently, 34 stations submitted data, and the collection and quality check activity has also been done in conjunction with the other global initiative (FLUXNET-CH_4, where RINGO is a crucial partner).

In the same period, UNITUS participated in discussions and meetings about the development of the new protocol (in particular with the ICOS community at the ecosystem MSA and with the American community at the AmeriFlux annual meeting). In this context, a poster on the importance to measure the Storage component (to add at the turbulent flux) and the possibility to use also cheap IoT sensors has been presented with a poster by Nicolini et al. at the AGU2018 and AmeriFlux2019 meetings (activity also linked to WP5). UNITUS is also working on a statistically robust tool for the timelag estimation in case of small fluxes that will be added to the standard QC pipeline implemented in the ICOS ETC; a publication is expected in 2020. The main activity is, however, expected when the results from the task will be defined and will need an implementation in the ICOS processing.

Partner: 27-DWD

Description of work carried out in T3.4 by beneficiary:

Beneficiary 27-DWD contributed to D3.5. and MS54 by a re-analysis of CH_4 flux data from the ICOS site DK-Skj (Skjern wetland in western Jutland, Denmark). We focused on the identification of driving variables for methane fluxes and considered the relevance of the time scale at which flux data are correlated with meteorological, hydrological, and management induced control factors. The analysis, carried out by the use of artificial neural networks (ANNs), demonstrated the importance of a driver analysis as a prerequisite for any sophisticated gap-filling procedure.

Significant results:

When half-hourly CH_4 flux data are considered, the position of the water table was identified as the primary driver at the restored wetland, followed by wind direction (becoming the primary driver in winter when the water table was permanently high) which mirrors some degree of spatial heterogeneity at this associated ICOS site. Interestingly, the next important driver in autumn and winter was u_star, which points at the importance of an appropriate u_star filtering procedure in the data analysis that accounts for potential biases in (gap-filled) flux totals induced by a too generous removal of low turbulence flux data. Soil temperature came next in the ranking of the most relevant driving factors for half-hourly CH_4 fluxes. However, when looking at daily fluxes and considering the whole year, soil temperature was identified as the primary driving factor, followed by water table position and then wind direction. Analysing summer data only, the ranking of the drivers was similar for both time scales. A publication of these results is in preparation, and the findings contribute to the continuous improvement of the protocols for non-CO_2 eddy covariance measurements.

Partner: 11-ETH

Description of work carried out in T3.4 by beneficiary:

Beneficiary11-ETH (Grassland Sciences group: Prof. Nina Buchmann, group leader; Lukas Hörtnagl, data scientist; data collection supported by the technical assistance of Paul Linwood) contributed to D3.5 and Milestone MS54 by (1) coordinating the collection of available N_2O and CH_4 non-CO_2 eddy covariance raw data files on dedicated servers at ETH Zurich, (2) disseminating the collected raw data files among T3.4 partners, i.e. the ICOS Ecosystem Thematic Centre for the development of the ICOS non-CO_2 data processing chain. In addition, (3) selected sites from the collected non-CO_2 datasets constituted the basis for subsequent analyses and tests, in particular with regards to improving data post-processing of N_2O fluxes.

Two post-processing steps crucial for the calculation of non-CO_2 annual budgets were investigated in detail: u* filtering and gap-filling. To this end, a software tool specialized in analysing time series data in real-time was developed and subsequently applied to pursue open questions relevant to ICOS. The software consists of multiple modules with different functionalities that can be accessed and freely combined using a graphical user interface. The source code (Python), along with detailed documentation, will be published in 2020 (open source, peer-reviewed).

Due to the open nature of the software, it was possible to investigate the combined effects of different post-processing steps on non-CO_2 budgets of different ecosystems. For these analyses, we focused on the intensively managed grassland CH-Cha (fertilized, 3 years of data), the ICOS Class 1 forest site CH-Dav (2 years of data), and the cropland CH-Oe2 (crop rotation, 6 months of data). Central aspects investigated for RINGO were: (a) the potential impact of u* filtering on annual non-CO_2 budgets from high-flux sites and low-flux sites; (b) the applicability of machine learning algorithms (random forest) to gap-fill N_2O fluxes and (c) in assisting model feature selection during model development.

Significant results:

(a) USTAR: The impact of u* filtering is potentially high at high-flux sites, especially fertilized agricultural sites where episodic non-CO_2 emission bursts are often recorded after fertilizer application or rain events. Flux data availability around such high-emission events needs to be as complete as possible for an accurate gap-filling of flux data gaps. At low-flux sites and in the absence of episodic peak emissions, the impact of u* filtering is expected to be generally low. At such sites, flux values are close to the detection limit and often fluctuating around zero throughout the year, i.e. even many data points lost due to u* filtering can be gap-filled with relatively high confidence.

Therefore, it is advisable to keep data loss due to u* filtering at a minimum, in particular for agricultural sites. Analyses have shown that the single yearly overall threshold that is typically applied to annual CO_2 datasets is often dominated by threshold values found during winter, which are often statistically different (biased high) from the seasonal thresholds found for spring, summer and autumn. However, fertilization and other management events take place during the warmer time periods, when u* thresholds are considerably lower (better turbulence conditions).To minimize data loss due to the u* filter, it is, therefore, advisable to use seasonal thresholds detected for the CO_2 flux instead of one single threshold for the complete year. Currently, there is one manuscript in preparation that investigates the seasonal detection of u* thresholds in the context of non-CO_2 fluxes and its impact on the annual GHG budget in detail.

(b), (c) GAP-FILLING: Testing machine learning algorithms to gap-fill N_2O fluxes revealed random forest (RF) as a suitable ensemble learning method to create complete, gap-less flux datasets. Other gap-filling methods yielded annual N_2O budgets often similar in magnitude to RF, but they arrived at similar budgets for the wrong reasons and must be applied with care.

For example, the N_2O budget calculated with different methods that yielded similar results for the intensively managed grassland CH-Cha in the time period 2013 – 2015 were (more results from other methods are available upon request): 15.2 kg N_2O-N ha-1 (RF), 15.5 (Marginal Distribution Sampling technique-MDS with the CO_2 drivers SW_IN, TA, VPD), 15.2 (*simple linear interpolation* (SL) with no gap size limit) and 15.2 (*simple running mean* (SRM) in a time window of ±2.5 days).

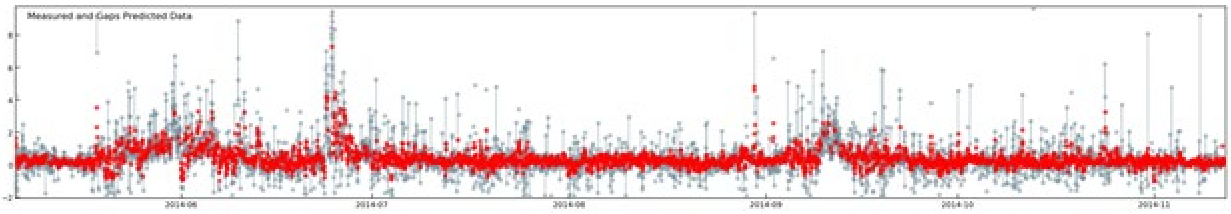


Figure 28. Gap-filled (random forest, red) and measured (after quality control, blue) half-hourly N_2O fluxes. Emission peaks were observed after the application of slurry to the grassland. Slurry application dates: 26 May 2013, 25 Jun 2014, 9 Sep 2014.

In RF, a large number of decision trees operate as an ensemble: the most "voted for" class prediction becomes the model prediction. This approach worked well not only for gap-filling N_2O data (even in the presence of emission peaks, see Figure 28), but also for model feature selection from large auxiliary datasets. During our tests, RF identified the variable time since last slurry application as the most important model feature, which highlights the urgent need to collect and share management data.

The application of MDS with CO_2 drivers is counter-intuitive since the three input drivers had no predictive power for observed N_2O exchange rates. Since MDS applies look-up tables, it seems to make sense that it nevertheless yields annual budgets that fall into expected ranges.

Budgets calculated with the straight-forward SLI is not recommended. SLI is extremely volatile to the length and distribution of gaps, and the risk to significantly over- or underestimate the true budget is high. However, it is potentially useful in connection with other gap-filling methods, e.g. to fill the smallest gaps in the dataset (e.g. 1-2 missing half-hourly values) before proceeding with other methods. In our test setup, SLI yielded virtually the same result for the grassland, mainly because (1) the available data around fertilization events was relatively complete, (2) there were no major gaps throughout the 3-year period, (3) high fluxes were underestimated and (4) low fluxes were overestimated. For the forest site, the dataset of which was characterized by several weeks-long gaps, SLI did not produce a realistic budget.

The SRM in a time window short enough to capture peak dynamics produced results similar to RF when the gap distribution of the dataset after quality control was approx. evenly distributed over the year, and no major gaps (longer than five days, i.e. ±2.5 days) were present in the dataset.

Partner: 8-NERCCEH

Description of work carried out in T3.4 by beneficiary:

Beneficiary 8-NERCCEH contributed to D3.5 by leading on the publication of the first international protocol for N_2O and CH_4 eddy-covariance fluxes. This first protocol recommended the development of an additional experimental method to assess instrument performance and data processing. NERCCEH responded to this challenge by designing and testing an automated overflow inlet for non-CO_2 GHG eddy-covariance measurements. This inlet was designed to continuously and experimentally assess the detection limit, response time, and lag-time of the flux systems during times when fluxes are too small to be calculated with conventional numerical approaches. The inlet was tested during two periods

at NERCCEH's local Easter Bush agricultural measurement site, using a quantum cascade laser system for N_2O and CO_2, and provided an in-depth data analysis. NERCCEH contributed to the WP meeting in Southampton and the WP-wide discussions on spectral correction and instrument synchronization.
Beneficiary 8-NERCCEH contributed to Milestone MS54 by leading on the publication of the first international protocol for N_2O and CH_4 eddy-covariance fluxes.

Significant results:

The overflow inlet proved a highly successful and robust method to improve EC flux estimates for fluxes near the detection limit and is recommended for implementation where a tracer with larger fluxes is not measured within the same instrument. During periods of large fluxes, the experimental method agreed well with the numerical methods. During periods of small fluxes, the use of the experimentally derived instrument characteristics provided much cleaner analysis products.
A paper for Atmos Meas Techniques is in an advanced state of preparation.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

No deviations from the DoA. For the last month of RINGO, NERCCEH changed into UKCEH following a change in ownership and governance of the institute.

Partner: 22-DTU

Description of work carried out in T3.4 by beneficiary:

Beneficiary 22-DTU contributed to D3.5. and Milestone MS54 by designing a study on two alternative ways to correct non-GHG flux measurements for spectral attenuation, spectral fits to co-spectra (SF_Co)versus spectral fits to power-spectra (SF_Po). In a pre-study, the two methods were implemented to own N_2O flux data from an earlier InGOS campaign at Risø, Denmark. The results are shown below. From this study, we derived a protocol to systematically test the effects based on artificially degraded (low-pass filtered) flux data that were amended with different degrees of noise. This protocol allows to test the factors, degree of low-pass filtering, and signal to noise ratio on the performance of the two methods. The concept was handed over to a working group, including a young scientist at UoH, for implementation and test on a broader data basis. Our contribution to these activities, which will be reported elsewhere, was the supervision of the work, including discussion of results and documentation.

Task 3.5 Developing ICOS Ecosystem network to nodes for general Ecosystem observations

Task leader: UNITUSINRA (11); Participants: UAnt (1)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS35	International workshop on enhancing ICOS Ecosystem sites to become sentinel sites in cooperation with other domain-specific ESFRI and global infrastructure held	WP3	3-UNITUS	24	This MS will be finalised as a side event to ICOS science conference

Partner: 3-UNITUSINRA

Description of work carried out in T3.5 by beneficiary:

Beneficiary 3-UNITUSINRA contributed to Milestone MS30 by developing the concept of virtual network optimization, which was applied in a case study on CO_2 impact on annual GPP.

Significant results:

The task focuses on the analysis of the capacity of the ICOS station network to detect and quantify the temporal and spatial variations in CO_2 fluxes exchanged between land and atmosphere and to attribute them to environmental and management drivers. From a prospective analysis of the expected impacts of environmental changes on ecosystem-atmosphere exchanges, task 3.5 identifies the main improvements needed in terms of geographical and climatic coverages as well as measurements completeness, consistency and accuracy to enable the ICOS Ecosystem network to quantify temporal changes in GHG fluxes to be expected for the ICOS whole life duration and attribute them to causal factors. This specific tasked started in April 2018 with the hiring of a research engineer.
Three phases were identified within this task and were summarized in the previous intermediate report as: Phase A. Metrological performances of the Ecosystem network; Phase B. Attribution and Phase C. Roadmap.
This second periodic report describes the concept of virtual network optimization that we implemented in the context of Phase A, B, and C, and a case studied based on CO_2 impact on annual GPP is described.
The work consisted in determining the minimum requirement in terms of measurement duration and/or number of stations needed to detect a linear trend in a given variable, e.g. as due to a drift of an environmental factor, and considering the uncertainty on the measurement and the inter-annual variability. We applied this concept to the case study based on the analysis of the impact of CO_2 concentration increase on annual GPP: what is the minimum duration required / and or number of stations needed to detect a potential change in annual GPP of 0.5% per year due to an increase in [CO_2]. The variable GPP is modelled as the sum of a mean value, a CO_2 effect, an error in measurement and interannual variability. We used the Fluxnet 2015 database to assess the error and interannual variability of historical stations and a process-based model to estimate the impact of CO_2 increase on annual GPP.

1. Design of a virtual network

Concept
The objective was to analyse the performance of a network of stations measuring a variable modelled as described above. We created a virtual network composed of random time-series per measurement stations, representative of a variable with its uncertainty and temporal variability.
The variable values were normalized so that the temporal change and the variability of the studied variable is expressed in percentage. A range of temporal change rates (linear regression slope), errors and IAV were considered (in a range representative of what was observed) based upon legacy data analyses and for different network designs in terms of station numbers and measurement duration. This part will be further described (section 2.). An ensemble of possible datasets measured by the station network was simulated by Monte Carlo approach, using the models of the distribution of errors and IAV fitted on legacy data, i.e. a Normal and a Gamma distribution respectively. From the ensemble of simulated values, we calculated the number of stations/number of years that are needed to detect the change in the studied variable with p=0.95.
This methodology is based on a similar statistical analysis developed in Baldocchi et al. (2018), but adding a new dimension to the analyses, i.e. the number of stations considered in the network and some adjustments of error estimation.
Hypotheses
The virtual network construction is based upon the following assumptions:

- For each station and time, a dataset of 2500 values of the variable is created (Monte Carlo).
- Stations in the network are representative of a homogenous domain, with similar expected change in a variable and similar uncertainty on the measurements
- The change (slope of the regression) is linear
- The overall variability - denoted as $\boldsymbol{s}$ - represents a total variability which includes a detrended natural variability (e.g. InterAnnual Variability, IAV) and a term of uncertainty on the measurement ($\boldsymbol{\varepsilon}$)
- The distributions of the error ($\boldsymbol{\varepsilon}$) and IAV do not change with time.

All possible combinations of network size (number of stations =1 to 15) and measurement duration (t=1 to 25 years) is then composed, that is k=2500 time-series of var_{nz} values for each station number x time combination. Last a regression procedure is applied to each time series. The network is capable to detect the temporal trend when the regression is significant (a = 0.05) for > 95% of the 2500 time-series.

In what follows, statistical analyses were performed with SAS 9.4 Statistical Software Package (SAS Institute, Cary, NC, USA). The terms from Equation 1 need to be determined, which will be considered in the next sections.

2. Case studied: Impact of [CO_2] on annual GPP.

We are now presenting the specific case of detecting a CO_2impact on carbon fluxes, especially on the annual Gross Primary Production (GPP) across terrestrial ecosystems. This case is simple because CO_2 and its drift can be considered uniform across Europe and can be considered to increase continuously on an annual temporal scale, conditions that fit our previous hypotheses for creating the virtual network.

Analyses of annual GPP.

i. Data used

The annual FLUXNET2015 dataset was uploaded from fluxnet websites (ex. FLX_ IT-Col _FLUXNET2015_FULLSET_YY_1996-2014_1-3.csv). This represents a total of 170 sites. However, 147 sites provided annual values of GPP, equivalent to 1181 site years.

ii. Studied variable

The so-called 'GPP_NT_CUT_REF' from the FLUXNET2015 database was selected for the analyses. GPP corresponds to the annual Gross Primary Production in gC m^{-2} and is derived from NEE and assessed from the Nighttime partitioning method (NT, Reichstein et al. 2005). A reference GPP has been selected on the basis of the Model Efficiency (identified with "_REF" in the variable name). Starting from the 40 different GPP estimations (obtained by filtering the data with 40 different Ustar thresholds), it has been calculated the Model Efficiency between each version and the others 39. The reference GPP has been selected as the one with higher Model Efficiency sum (so the most similar to the others 39). 'CUT' refers to a Constant Ustar Threshold: all the thresholds found in the different years have been put together and final thresholds extracted from this dataset (each year filtered with the same Ustar threshold).

For a given site, the average annual GPP and the standard deviation were calculated.

When combining the 147 sites, we obtained an average GPP of 1243 gC m^{-2} and an average standard deviation of 261 gC m^{-2}; which corresponds to 21% of GPP. We looked at the distribution of the standard deviation.

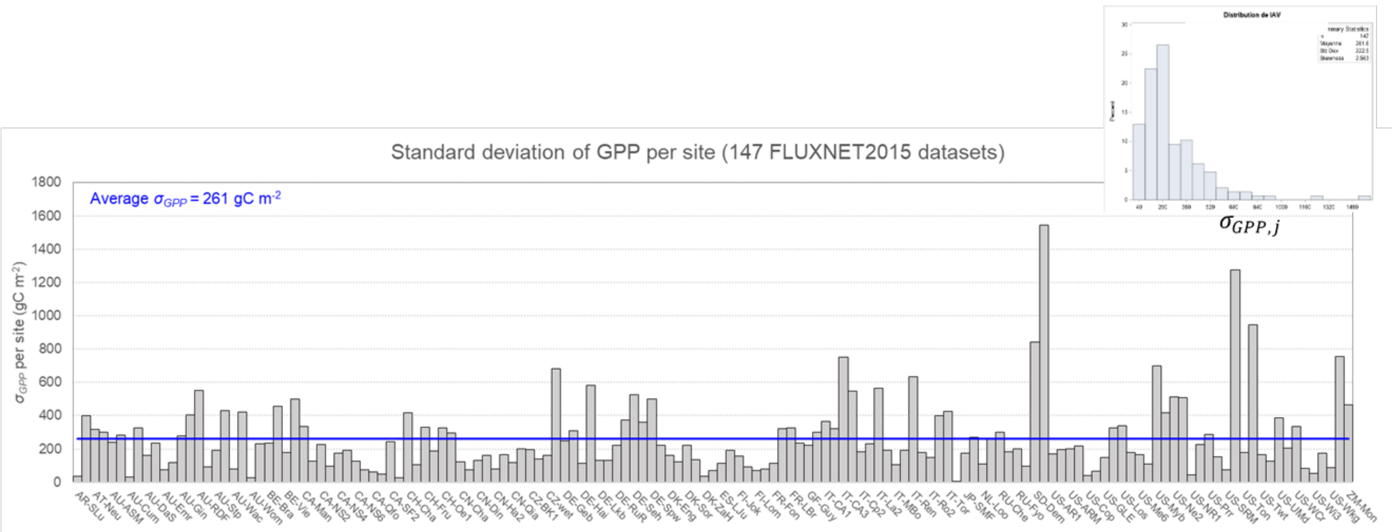


Figure 29. Standard deviation of the average annual GPP per site and histogram of the distribution (bins= 80).

For a station j, the total variability can be decomposed into two terms , IAV, the Inter-Annual Variability and e, the uncertainty on annual GPP.

iii. Analysis of the variability of GPP given by the standard deviation :

In order to create a time series representative of the FLUXNET2015 datasets, we fitted different distribution laws to the distribution of the standard deviation of GPP per site.The gamma distribution was selected as the best representation of the distribution.

iv. Uncertainty in the studied variable

In the context of the optimization of a network, an important dimension of our virtual network is the uncertainty e. This uncertainty derives from NEE measurement that itself leads to two types of uncertainties: systematic and random uncertainties (Moncrieff et al. 1996). The first one includes frequency response errors (instrument time response, tube attenuation, path and volume averaging, sensor separation, sensor response mismatch, low and high pass filtering, and digital sampling) as well as physical consideration (spikes and noise in the measurements, unleveled anemometer, wind angle of attack, sensor time delay (especially important in closed-path analyzers with long intake tubes), sonic heat flux errors, the Webb-Pearman-Leuning density terms (WPL), instrument calibration, gas flux storage and finally u* filtering. The random uncertainty instead refers to the stochastic nature of turbulence, i.e. the sampling error expressed by the flux error of the covariance (Finkelstein and Sims, 2001; Salesky et al. 2012) and the error due to the instrumental noise (Lenschow et al. 2000; Billesbach (2011).

FLUXNET2015 database represents the opportunity to assess an uncertainty on GPP calculated from the Net Ecosystem Exchange (NEE) and the Ecosystem Respiration (Reco) in a homogeneous way across sites. Indeed, this is the first database combining different sources of uncertainties in a JOINT UNCERTAINTY variable, which includes the random uncertainty and the Ustar filtering uncertainty. Similarly to what was presented above (GPP_NT_CUT_REF in §2. a. ii.), the joint uncertainty was assessed for the variable NEE_CUT_REF. The random uncertainty in the measurements is estimated on the half-hourly data and quadratically summed for the other time scales. This methodology is based on the random uncertainty computation of Richardson et al. (2006). As a self-differential approach, it is a direct standard deviation method that requires measured values with similar meteorological conditions within the sliding window: For a sliding window of +/- 7 days and +/- 1 hour of the current timestamp, RANDUNC is calculated as the standard deviation of the measured fluxes. The meteorological conditions must also be sufficiently similar, i.e., air temperature ±2.5 °C, Vapor Pressure Deficit ±5 hPa, Incoming Shortwave Radiation ±50 W m^{-2} (if radiation is higher than 50 W m^{-2}) or Incoming Shortwave Radiation ±20 W m-2 (if lower than 50 W m^{-2}). Ustar threshold is estimated by the Moving Point Test, according to Papale et al. (2006), and the estimation of uncertainty of the threshold is processed by bootstrapping the data within one year.

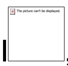
We consider that the uncertainty in GPP arises from the error on both nighttime NEE and daytime NEE and is therefore computed as the quadratic sum of the error in nighttime NEE and daytime NEE. On average for the 147 sites, the annual uncertainty on annual GPP represented: 155 gCm^{-2} y^{-1} for an average GPP of 1243 gC m^{-2} $y^{-1,}$ which corresponds to 12.4% of GPP.

Analyses of [CO_2] evolution and its impact on annual GPP

The impacts of CO_2 are well documented, especially on GPP, and they can be simulated using processed based models developed for different ecosystems types. In our example, we conducted a simulation with GO+ model (Loustau et al. 2005, Ciais et al. 2011, version 27.0 => Moreaux et al. tbs) to assess the impact of CO_2 increase on annual GPP. The model GO+ has been developed along a series of experimental and theoretical developments. The model can be applied to various species (Eucalypt, Douglas fir, Coffee, European Beech, maritime Pine) and management schemes (standard, coppice, agroforestry). In this exercise, GO+ was parameterized for a temperate evergreen needleleaf forest (FR-LBr in the FLUXNET2015 database). Two runs were considered:

- Run1 : control : « Const » CO_2 concentration was set constant at an initial value of 343 ppm 1984 to 2010.
- Run2 : historical : « Hist » CO_2 concentration followed the historical record from 343 ppm to 390 ppm from 1984 to 2010.

Comparing the GPP outputs of the two simulations, we found that the difference between GPPhist and GPPconst reached 170 gC m^{-2} y^{-1} in 2008. This represents a change of 6.8 gC m^{-2} y^{-2} over the 1984-2008 period, i. e +0.40% per a.

Several questions arise from this: How long before the modelled CO_2 impact until , also accounting for GPP annual variability and uncertainty, can be detected, with one station? With a network? How many stations are needed?

To take into account the impact of CO_2 increase on GPP, in what follows, we will consider a slope in annual GPP ranging from 0.5 to 5%.

3. Network implementation

a. Concept scheme

Taking into account the previous results, we were able to create a virtual network with the dimensions described in Table 3.3. The dimension « ε » and « sl » ranged respectively from 2% to 18% and from 0.5% to 5% respectively, to be representative of what was studied above and the total variability and uncertainty followed the proposed distributions. The simulations are carried out subsequently for time series ranging from 3 to 25 years in a network composed from 1 to 15 stations. From Equation 5. We can add an Inter Annual Variability to var_{nz}based on the analyse in §2. a. iii. Implementation of the model and statistical analyses were performed with SAS 9.4 Statistical Software Package (SAS Institute, Cary, NC, USA).
For each combination, we are computing the regression slope between varnz and year (t-Student on the slope). We are then determining the P-value of this regression (2500 P-values). The univariate procedure in SAS allows to compute P95, i.e the P-value at the 95th percentile. If this P-value is lower to 0.05, then we can consider this combination significant. This P-value refers to a specific case of a combination {year, station, slope, uncertainty} and, therefore, can be interpreted as detectable thresholds.

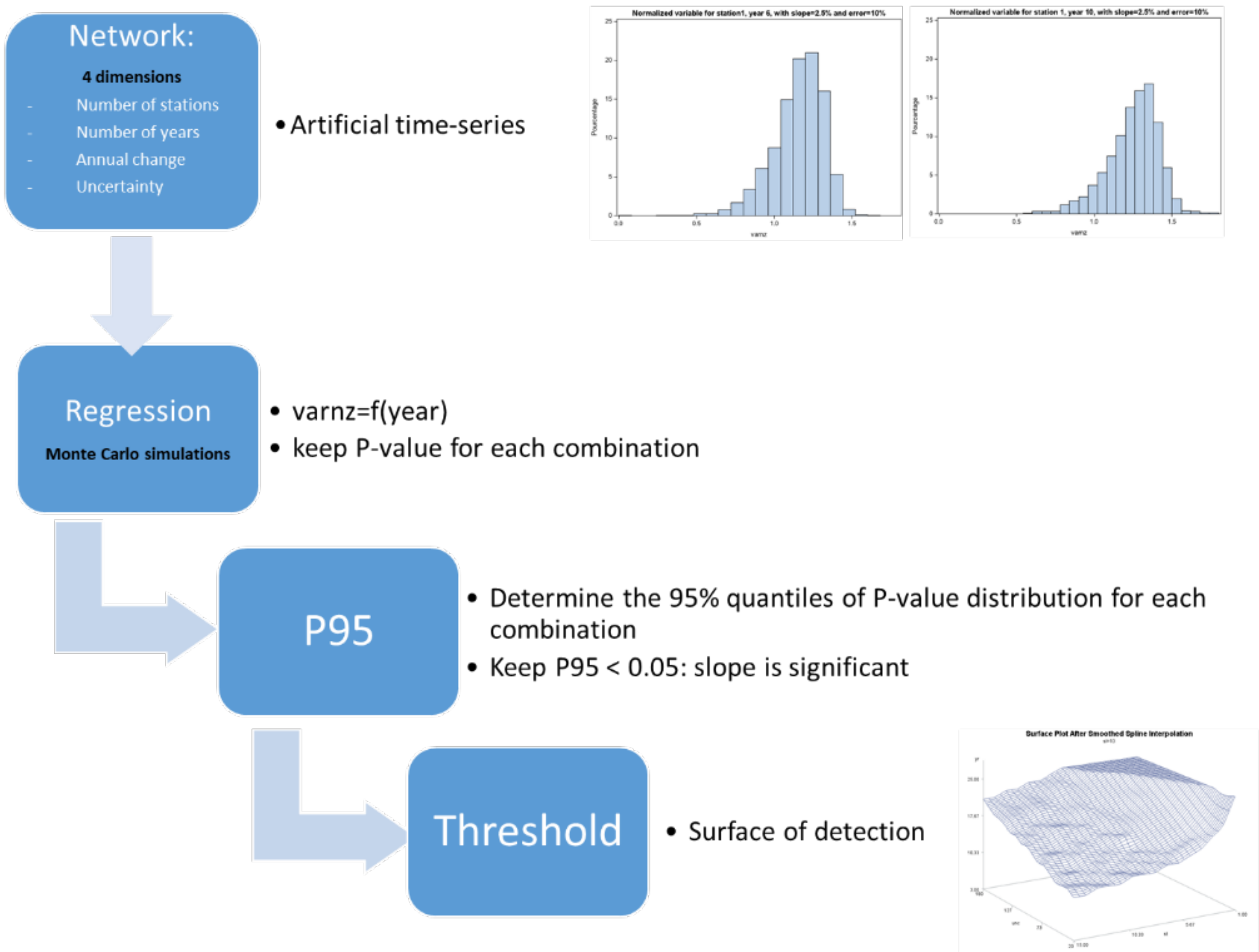


Figure 30. Concept scheme of the network optimization.

Table 3.3 Simulation plan

Variables and parameters	Start	End	by	Nb runs
Temporal scale : year ***t***	3	25	1	23
Station ***j***	1	15	1	15
Error ***ε***	2%	18%	1%	17

Slope ***sl***	0.50%	5%	0.50%	10
Monte Carlo ***k***	1	2500	1	2500
Total number of runs				146625000

4. Results

The graphs provide a strategy toward the best possible trade-off between accuracy and network size in order to detect a change in a selected variable due to a drift in an environmental parameter, in this specific case: modelling the sensitivity of station network to the [CO_2] drift.

Smoothed surfaces indicate the time requested for the network to detect with α=0.05 (Monte Carlo, n=2500), a significant (P-value < 0.05) linear trend (t Student on slope) in GPP, with a certain number of stations in the network. The profile of each adimensioned “detection surface” indicates the gain in sensitivity of the network for each additional station and accuracy level and allows therefore to optimise a network configuration in terms of environmental sensitivity.

Figure 31 shows for instance that increasing the number of stations is critical for detecting subtle changes (***sl***= 0.005 to 0.01 yr-1) but adding supplementary stations beyond n = 10 would be no more requested for more drastic changes (***sl***>0.025 yr-1). Increasing accuracy (surface profile along the y axis) is efficient even for a large network and drastic temporal changes.

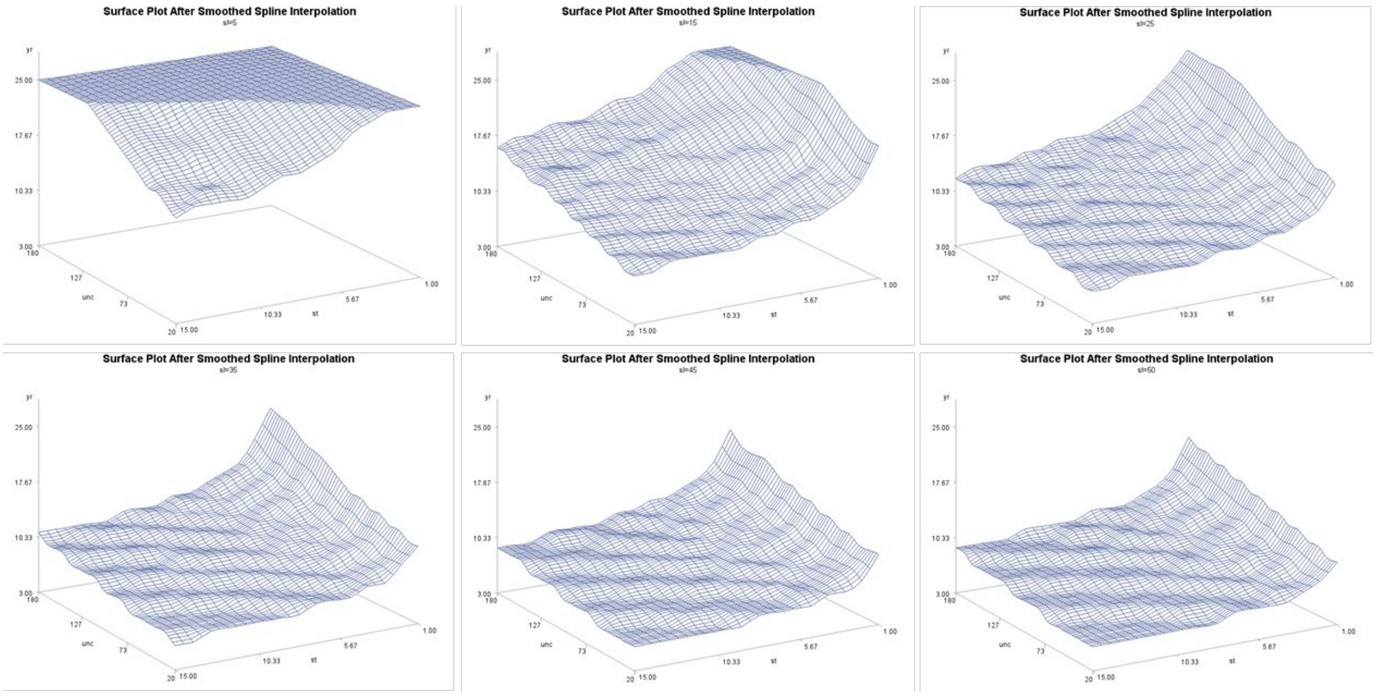


Figure 31. Surface of detection of different change (from *sl* = 0.5% to *sl*=5%). X-axis represents the number of stations in the network (from 1 to 15), y-axis represents the annual uncertainty (from 2% to 18%) and z-axis the number of years needed for detecting the change.

5. Extrapolation to network optimization for 2020-2050

From the theoretical approach and from the existing 2018 stations network, we were able to simulate the potential changes in FCO_2. In the next step, we will define a domain in accordance to an ecoregion in reference to Hill et al. (2017). This implies that we can partition the European area within the ICOS network and potential extension, among n homogenous zones being affected uniformly by the environmental changes. For each of the eco(iso)zones, we will explore the expected change in meteorological parameter as well as bio-chemical parameters and their potential impact on GHG fluxes, both in a literature review analysis and with model simulations.

In order to simulate atmospheric chemistry trajectories, we worked in partnership with the CNRM-Meteo France (Virginie Marecal, Béatrice Josse, and Kévin Lamy, 3 months convention), using their chemical transport model (CTM) MOCAGE (Josse et al., 2004; Teyssedre et al. 2007). This model was able to

simulate the variables of interest at an hourly basis for the historical period 1995-2015 and for the 2015-2050 period with a spatial resolution of 0.5°×0.5° across Europe:
- Concentration (ppb) and wet/dry deposition of ozone O_3 (mol m^{-2} h^{-1}).
- Concentration of nitrogen oxides (NOx as NO, NO_2, and NO_3)
- Nitrogen wet and dry deposition (NO_2 et NO_3)

MOCAGE uses climate projections from the ARPEGE-Climat GCM in its native global grid with a resolution of 0.5° over Europe. For the projections (2015-2050 period), the RCP4.5 climate scenario, and the ECLIPSE anthropogenic emissions v4.a scenario for air pollutant emissions were used (http://eclipse.nilu.no/). The latter corresponds to the annual sums of emissions of different components following the Maximum Feasible Reduction (MFR) legislation. Time disaggregation to hourly scale was obtained from GENEMIS data (Ebel et al., 1994) using hourly coefficients depending on the activity sector(Society, 1994).

6. Next steps: Milestone and deliverables

January – April 2020: Improvement of the theoretical optimization network model and application to legacy data. Submission of a paper showing the capacity of the actual network to have been able to detect the rising CO_2 concentration impact on GPP.

February 2020: MS35 1st part: During the ENVRI WEEK (Dresden, Germany, 3-7 February 2020), we are organising a meeting with the ENVRI infrastructures.

June 2020 (extension obtained from M42 to M48due to the absence of the engineer hired and in a maternity leave in 2019**)**:D3.6 Proposition of a roadmap (phase C) for enhancing ICOS Ecosystem sites to become sentinel sites in cooperation with other domain-specific ESFRI and global infrastructure. We will propose a roadmap (phase C) to optimise the ICOS ECO network in terms of performance, coverage (ecosystems, climate, soils, pollution exposure), inter-operability, and completeness. We will make recommendations about the geographical coverage, environmental spectrum coverage, and completeness of ICOS Networks and extend this recommendation to Environmental infrastructures and demonstrate how inter-operability among networks could help to assess the impacts of climate, pollution, and management on European ecosystems.

September 2020:MS35 2nd part. During the ICOS conference, we will organise a workshop with other infrastructures, as a side meeting of the conference. The main title refers to: "Enhancing *in situ* observation network for detecting and attributing the environmental impacts on land ecosystems 2020-2040," and this side meeting aims at gathering the other domain-specific ESFRI and global infrastructures.

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Submitted and under review articles under RINGO financial support:
Moreaux V., Longdoz B., Berveiller D., Delpierre N., Dufrêne E., Bonnefond J-M., Chipeaux C., Joffre R., Limousin J-M., Ourcival. J-M, Klumpp K., Darsonville O., Brut A., Tallec T., Ceschia E., Panthou G., Loustau D. Environmental control of land-atmosphere CO_2 fluxes from temperate ecosystems: a statistical approach based on homogenized time series from five land-use types. *under review in Tellus B.*
Moreaux et al. 2020 : Mechanistic modelling of the energy, water and carbon exchanges in managed forest ecosystems : description, sensitivity analysis and evaluation of the INRA GO+ model, version 27.0. *to be submitted to Geoscientific Model Development*
[oral communication] Moreaux V., Gielen B., Papale D., Loustau. 2019. Optimising observation networks for the early detection and unequivocal attribution of environmental effects on European forests. IUFRO International Congress, Curitiba, Brazil, 29 sept. 5th Oct 2019. 20 pl. https://www.iufro.org/fileadmin/material/events/iwc19/iwc19-abstracts.pdf
[oral communication] Moreaux V. , Gielen B., Papale D., Loustau D. 2019. Enabling the observation networks of European Ecosystems to see the unseen: The sentinel network concept. ICOS 8th General Assembly – information day. 21st May, Saclay, France.
[oral communication] Loustau D., Moreaux M. 2020. Detecting together what you cannot see alone: the ICOS station network case. European Research Course on Atmospheres. Introductoral key note. Grenoble 13th Jan. 2020. CNRS- Université de Grenoble Alpes. 40pl
Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

Task 3.5 has been progressing smoothly and without major problems. Achieved a network performance analysis, presented at the IUFRO international workshop in September, https://www.iufro.org/fileadmin/material/events/iwc19/iwc19-abstracts.pdf and plan to submit a paper about this topic. The upcoming 20-year scenario of the climate of pollutants deposition on European ecosystems have been constructed in collaboration with CNRM team (B. Josse) using the chemistry transport model MOCAGE . Mrs V. Moreaux is now examining how well a station network may detect and attribute the expected climate and pollutants impacts across Europe from 2020 to 2040. Besides, contact were made with other infrastructure through the ENVRI FAIR project, and we intend to come back to them in February-March to elaborate together with the roadmap to optimised observations on ecosystems in Europe. Therefore, because the maternity leave of the main scientist recruited in this task has stopped the work programme for 5 months altogether,the complete Deliverable report on the delivery of the Roadmap towards optimised Ecosystem observations in Europe is postponed until the end of the project (June 2020). This delay will allow proper concertation with companion infrastructure to be organised following the next project Workshop (March 2020).

Partner: 12-UAnt
Description of work carried out in T3.5 by beneficiary:
Beneficiary 12-UAnt contributed to Milestone MS30 by participating in the optimisation part of task 3.5 through meetings, data analyses, discussions, and common presentations.
Significant results:
Description of the work, as provided by UNITUS-INRA and described above, is entirely shared with UAnt.

Work Package 4: Improving Data

Summary
Agreement has been reached on the mechanisms for live exchange of metadata within ICOS with regards to persons, roles, instruments, and stations between the ICOS Thematic Centers, Head Office and Carbon Portal, and the responsibilities for the updates. All TCs have started to implement part or all of the dynamic metadata exchange, and the Carbon Portal at ULUND/ERIC has set up the system to ingest and transfer the metadata into the central ICOS versioned RDF metadata store. The person and role information has been integrated with the dynamic data object landing pages to always show the up to date attribution information in the citation string for all ICOS observation data from Level 0 to Level 2. Within RINGO, we have now laid a firm basis for an improved and unified multi-domain ICOS metadata system.
All partners have worked on the provision of the improved legacy datasets for atmospheric CO2 and ecosystem CO2 fluxes. Due to work for the very successful Drought-2018 initiative and the pressure to deliver the legacy datasets for this initiative for an extended set of 48 atmosphere and 52 ecosystem stations, the delivery of the datasets by the TCs has been postponed to just after this reporting period.

List of deliverables due to be completed within this task within this reporting period:
D4.2: Ambient CO2 time series for the selected 10 measurement stations covering the period 2000-2015. [30] A dataset of at least 10 years of reprocessed ambient CO2 concentration time series for a set of maximum 10 stations in the pre-ICOS labelled period to complement the validated ICOS data products with a rich set of measurements of maximum compatibility in the pre-ICOS period.
D4.3: Reprocessed long-term data series from 9 ecosystem stations. [30]
A dataset of at least 10 years of reprocessed ecosystem CO2 eddy covariance flux data from up to 9 proposed ICOS stations will be prepared. Based on data collected in the pre-ICOS period (not following ICOS standards) will be available to complement the validated ICOS data products with a rich set of measurements with the maximum possible level of comparability.
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS36	Ambient CO2 time series for the selected 10 atmospheric measurement stations added to ATC data stream for ICOS QA/QC procedure	WP4	4 - UVSQ	24	Ambient CO2 time series for the selected 10 atmospheric measurement stations added to ATC data stream for ICOS QA/QC procedure
MS45	Ambient CO2 time series for the selected 10 atmospheric measurement stations published at carbon portal	WP4	1 - ICOS ERIC	30	Ambient CO2 time series for the selected 10 atmospheric measurement stations published at carbon portal
MS46	Reprocessed long term data series from 9 ecosystem stations published at carbon portal	WP4	1 - ICOS ERIC	30	Reprocessed long term data series from 9 ecosystem stations published at carbon portal

Contributions per task:

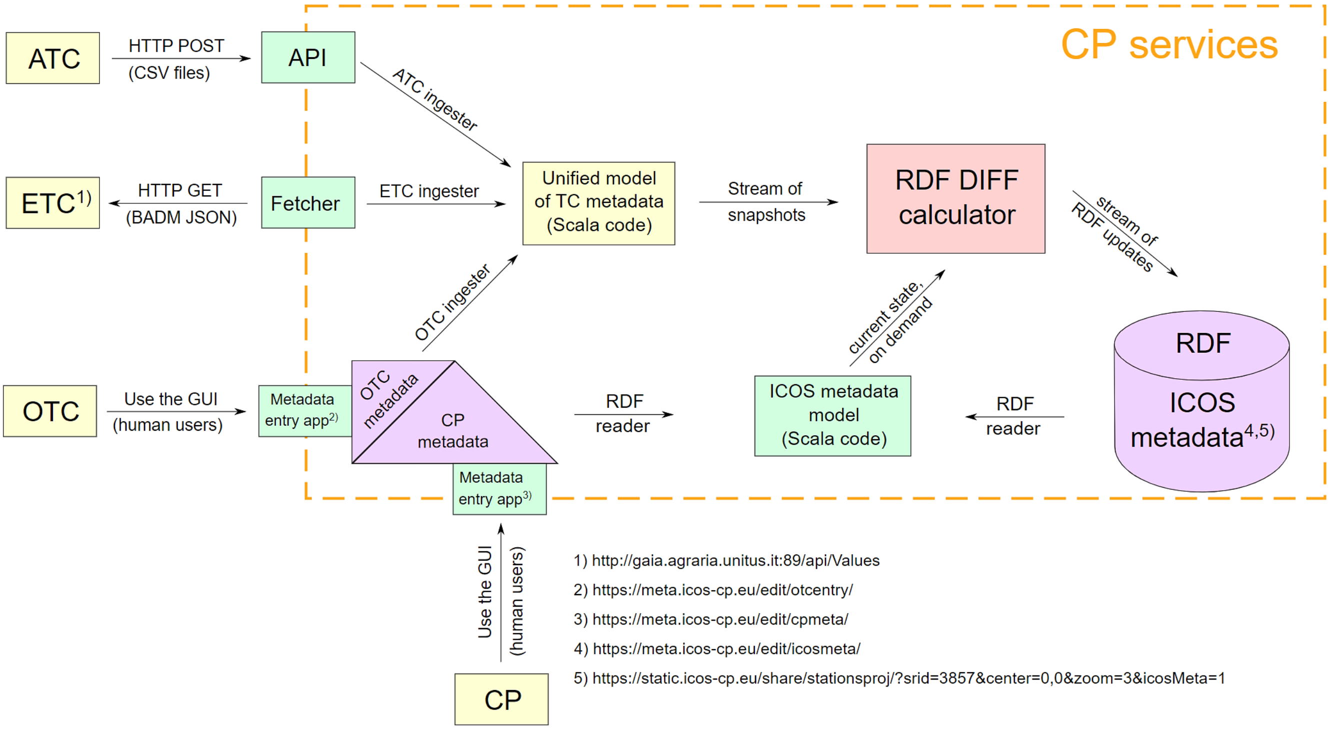
Task 4.1: Developing metadata for ICOS RI

Task leader: ICOS ERIC (1) Participants: UiB (3), UNITUS (5), UVSQ (5), UHEI (2), ULUND (15)

Partner: 1-ICOS ERIC

Description of work carried out in T4.1 by beneficiary

After some initial discussion on the working programme, the Data Lifecycle Working Group was formed in October 2018, consisting of representatives from all ICOS Thematic Centers, Head Office, and Carbon Portal. After three monthly telco's and discussion using a dedicated email list, agreement was reached on the principles of the metadata sharing, and the implementation of the improved workflows started. All three thematic centers choose for a different mechanism and format, fitting best with their systems, to exchange their metadata, and Carbon Portal agreed to unify all into a common metadata system that follows the FAIR principles and integrates well with the ICOS data portal workflow. A first working integration with the Ecosystem metadata was established already in February 2019. Progress and further work was also discussed in a separate session on the RINGO annual meeting in March 2019. All implementation lead to the detection of inadequacies in the incompleteness of available data, that were solved by one or more iterations of improvements at all sides. In summer 2019, the ATC delivered the first live update of the shared metadata for instruments and stations. OTC decided to use the semantic web ontology approach at Carbon Portal and implemented a detailed and sophisticated linked open data metadata ontology for persons, roles, instruments, and observation platforms that integrates immediately with the Carbon Portal metadata system. Just before the end of the period, all available metadata streams were integrated into the unified system that detects any changes in metadata from the Thematic Centres and stores this as versioned metadata updates in the RDF metadata store at Carbon Portal. The following diagram illustrates the process.



The attribution metadata for persons for as far as available from ETC and OTC was immediately used to update the dynamic landing pages concerning the citation of contributors to the ICOS L0-L2 datasets.

Next steps will be:

- to implement the dynamic citation for ICOS observational data also for Atmosphere as soon as the persons and role metadata becomes available from there
- to update the station landing pages, this will require that the TCs provide more detailed metadata information, like site descriptions, photos and site characteristics
- To add instrument information including provenance information to the relevant datasets' metadata
- The attribution information will also be used to automatically generate and update the author and contributor metadata in the Datacite DOIs for ICOS datasets and collections of data.

Significant results:
Agreement has been reached on the mechanisms for live exchange of metadata with regards to persons, roles, instruments, and stations between the ICOS Thematic Centers, Head Office and Carbon Portal, and the responsibilities for the updates. All TCs have started to implement part or all of the dynamic metadata exchange, and the Carbon Portal has set up the system to ingest and transfer the metadata into the central ICOS versioned RDF metadata store. The person and role information has been integrated with the dynamic data object landing pages to always show the up to date attribution information in the citation string for all ICOS observation data from Level 0 to Level 2.
Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions
Not all metadata required for the dynamic metadata system is supplied by the TCs. This is an ongoing work that will still require significant work and time. Also, new requirements arise from the fairness assessments done in the ENVRIFAIR that will require (small) changes and additions to the metadata exchange, and the ENVRIFAIR project also provides the resources to continue this work. Within RINGO, however, we have laid a firm basis for an improved and unified multi-domain ICOS metadata system.

Partner 2-UiB
Description of work carried out in T4.1 by beneficiary:
The ICOS Carbon Portal has developed a comprehensive metadata repository covering the requirements of all the Thematic Centres in the ICOS project. A metadata model for the OTC has been developed based on the manual, spreadsheet-based system currently used by the global marine

biochemistry community and which has been adopted by the SOCAT community. Transfer of the current metadata scheme into this new system at CP has started in will be finalized soon. As the metadata is added or updated, it is automatically attached to the relevant data sets and is available for download or through APIs for machine-to-machine transfer. Work is also under way to integrate the Carbon Portal's metadata repository for marine data with international efforts to develop a universal metadata editor to be used for a wide range of ocean observation data.

Significant results:

Metadata reporting is compliant with international agreed community standards and will be compliant with the newly developed United Nations Sustainable Development Goal 14.3.1 metadata methodology allowing for machine to machine exchange of ICOS metadata and data to responsible agencies. The methodology has been published in late 2019 - work on applying this high level effort is ongoing and will be finalised in summer 2020.

Partner: 3-UNITUS

Description of work carried out in T4.1 by beneficiary

A standard system to transfer the metadata from the Ecosystem Thematic Centre and the Carbon Portal has been agreed and implemented for the first set of data and information (site characteristics, site team members, instruments used). The number of metadata transferred will be increased in the next period.

Partner: 4-UVSQ

Description of work carried out in T4.1 by beneficiary

All instrument metadata and station metadata files are now sent automatically to the Carbon Portal daily. A few seconds after the push is complete, the updates are available on the Carbon Portal website. The instrument metadata is broken down in two parts (2 separate files):

- description of the instruments
- location of the instrument over time, including the heights they are recording from as this can also change over time.

The Carbon Portal has started to use the station metadata mid-January 2020. The landing pages of the data objects have been updated, they show stations' names and locations on the map (landing pages of the data objects, which show stations' names and locations on the map).

Although most urgently needed for attribution of current datasets, the metadata about people and roles will be the last piece to send to the Carbon Portal. It will be sent in the same automatic way that the other types of metadata. In order to be able to send this information, the ATC has to finalize the new rights/roles system set up as well as the mapping with DataCite. This mapping will allow the Carbon Portal to correctly define the citations for the data sets.

Significant results:

There were no Deliverables and Milestones due during Reporting Period 2.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

No deviations from the DoA and the planned use of resources.

Unforeseen subcontracting/in-kind contribution (if applicable)

No unforeseen subcontracting.

Partner: 10-ULUND

Description of work carried out in T4.1 by beneficiary

LU personnel carried out the work described under ICOS ERIC, under supervision of the CP director.

Significant results:

The unified and improved metadata system for ICOS observational data that describes persons, their roles, the stations, and the instrumentation, tightly coupled to the datasets.

Task 4.2: Making legacy data available

Task leaders: UVSQ (10), UNITUS (10); Participants: ICOS ERIC (2) UNITUSINRA (5), UHEI (3), UVGZ (5), ETHZEMPA (3), RUG (1), RUGECN (1), DWD (5), UHEL (5), UHELFMI (2), OMSZ (7)

List of deliverables due to be completed within this task within this reporting period:
D4.2 : Ambient CO2 time series for the selected 10 measurement stations covering the period 2000-2015. [30] A dataset of at least 10 years of reprocessed ambient CO2 concentration time series for a set of maximum 10 stations in the pre-ICOS labelled period to complement the validated ICOS data products with a rich set of measurements of maximum compatibility in the pre-ICOS period.
D4.3: Reprocessed long-term data series from 9 ecosystem stations. [30]
A dataset of at least 10 years of reprocessed ecosystem CO2 eddy covariance flux data from up to 9 proposed ICOS stations will be prepared. Based on data collected in the pre-ICOS period (not following ICOS standards) will be available to complement the validated ICOS data products with a rich set of measurements with the maximum possible level of comparability.
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS30	Raw data and ancillary data from 9 ecosystem stations compiled for re-processing	WP4	3 - UNITUS	20	Raw data and ancillary data from 9 ecosystem stations compiled for re-processing
MS36	Ambient CO2 time series for the selected 10 atmospheric measurement stations added to ATC data stream for ICOS QA/QC procedure	WP4	4 - UVSQ	24	Ambient CO2 time series for the selected 10 atmospheric measurement stations added to ATC data stream for ICOS QA/QC procedure
MS45	Ambient CO2 time series for the selected 10 atmospheric measurement stations published at carbon portal	WP4	1 - ICOS ERIC	30	Ambient CO2 time series for the selected 10 atmospheric measurement stations published at carbon portal
MS46	Reprocessed long term data series from 9 ecosystem stations published at carbon portal	WP4	1 - ICOS ERIC	30	Reprocessed long term data series from 9 ecosystem stations published at carbon portal

Partner: 4-UVSQ
Description of work carried out in T4.2 by beneficiary
The CO2 historical dataset have been collected from every partner. The initial target period was going from 2010 to 2015 (Figure 32). We have decided to extend this period until the end of 2017 in order to be able to supplement them with ICOS measures as far as possible. All those time series are part of the European data collection organized for the analysis of the drought 2018 (*Ramonet et al., in review*). In the context of the RINGO project, the objective is also to provide better traceability of the measurements, and to estimate the uncertainties. This involves collecting numerous meta-information in addition to observations. We have registered 34 analyzers used in the different stations in the ICOS database, which will allow us to associate each single measurement with a type of instrument (Figure 33), knowing that the historical time series combine different measurement techniques (gas chromatography, NDIR and CRDS spectroscopy). We also recovered information on all the calibration sequences carried out (Figure 34), as well as on the regular injections of a target gas when this information is available (Figure 35). One more piece of information to assess the data uncertainties comes from the comparison of the in-situ time series with flask measurements (Figure 36). From this information, the challenge in the coming months will be to estimate the uncertainties associated with the observations, depending on the instruments used, and the calibration strategies at the various stations.

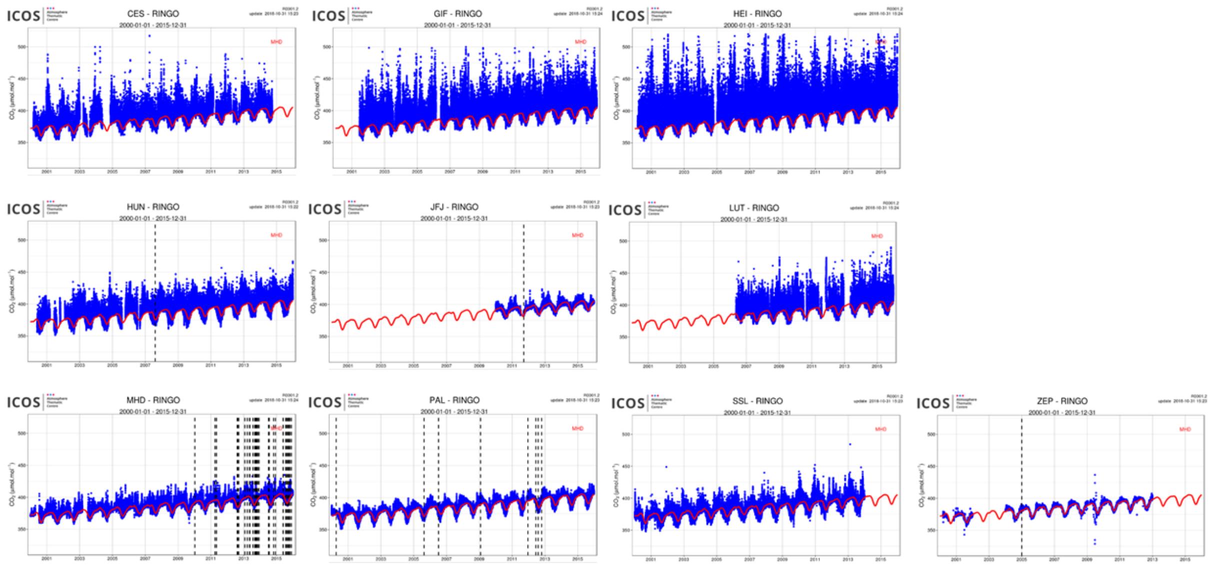


Figure 32. CO2 time series from the 10 atmospheric stations

Figure 33: List of instruments used for the atmospheric CO2 measurements

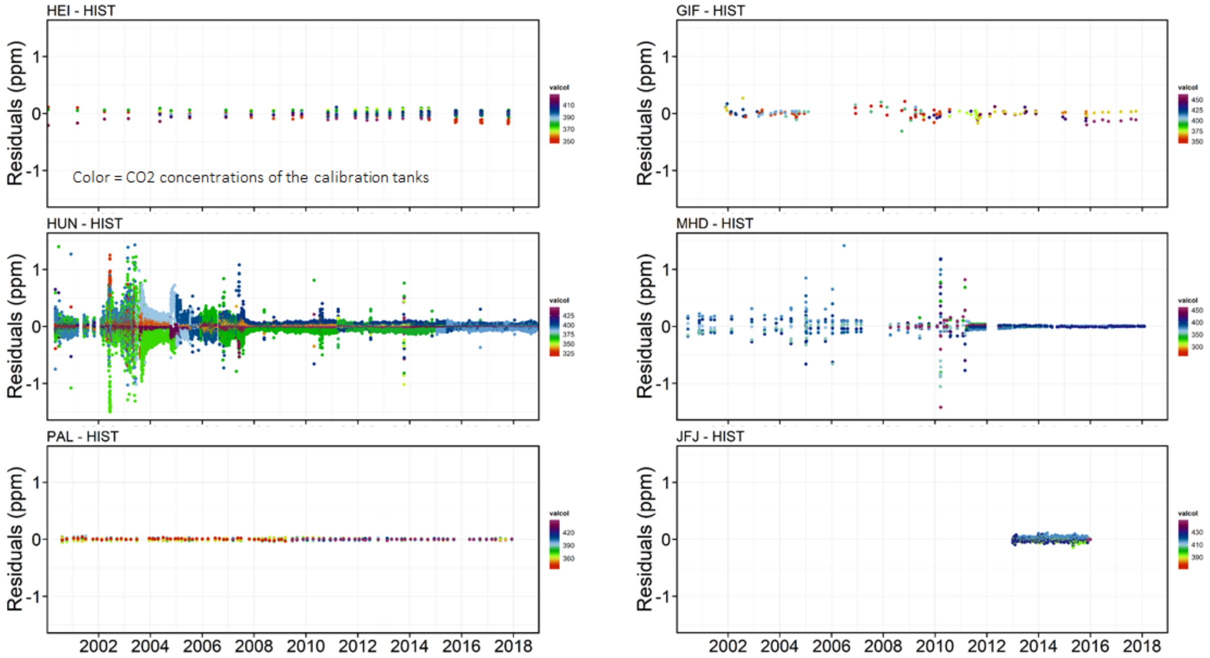


Figure 34. Concentration residuals from the calibration sequences at six atmospheric sites (the colors represent the CO2 concentrations of the calibration gases)

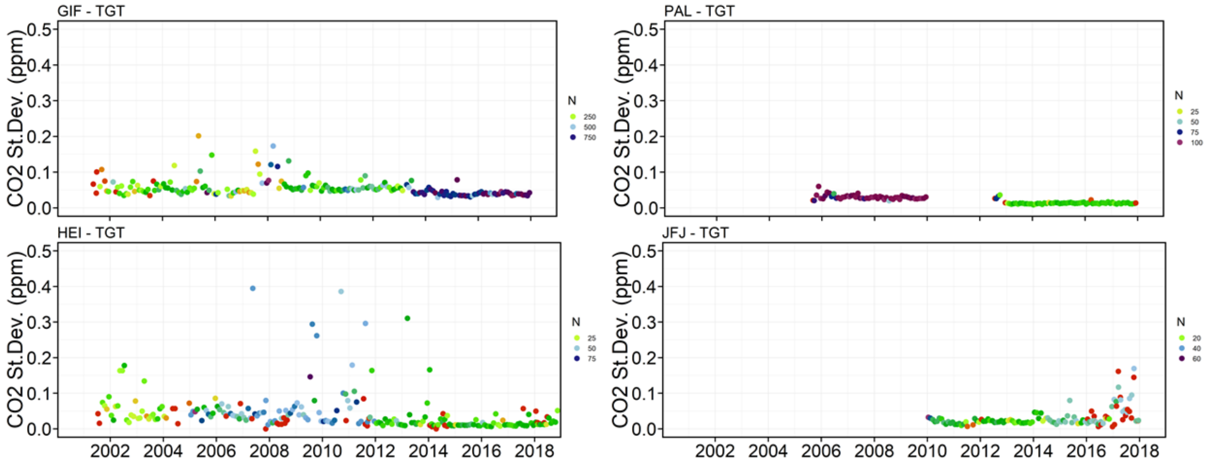


Figure 35. CO2 reproducibility estimated from a target gas measurements (the colors represent the number of target gas injections per month)

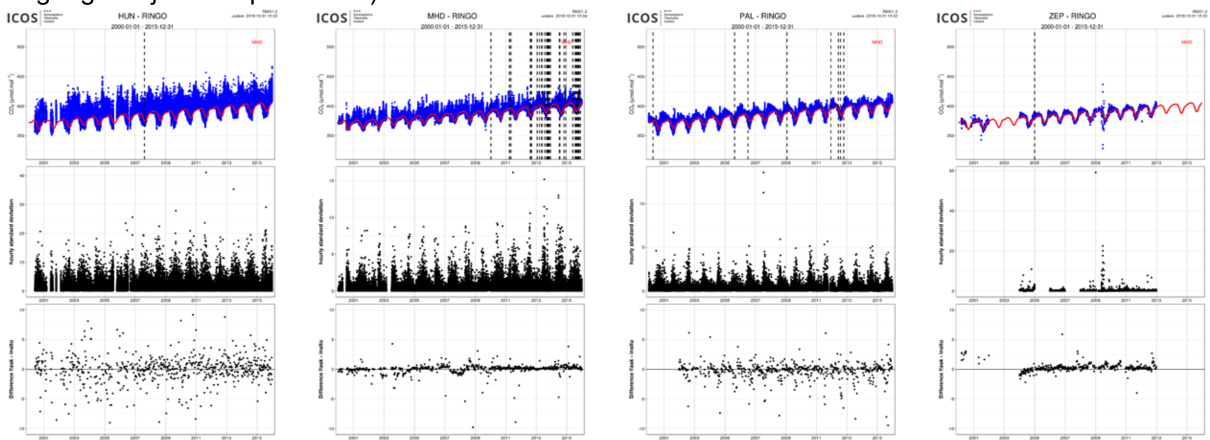


Figure 36. Comparison of CO2 concentrations between in-situ and flask measurements

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The Deliverable D4.2 is late with respect to the prevision. This is due to the amount of work needed for the data collection and transfer and the metadata preparation. However, all is ready for data preparation and release.

Partner: 3-UNITUS

Description of work carried out in T4.2 by beneficiary

In the second reporting period, the collection and check of data and metadata for the 9 stations where legacy data will be reprocessed has been completed. The nine sites and their characteristics in terms of setup for the pre-ICOS period are summarized in the figure here below.

SITES	Years (Non-ICOS)	setup Non-ICOS
BE-Lon	2006-2015	R3-50 & Li7000
CZ-Wet	2007-2011	R3-100 & Li7500
CZ-Bk1	2004-2011	R3-100 & Li7000
DE-Geb	2001,2002-2015	R3-50 & Li6262, R3-50 & Li7000
DE-Tha	2000-2006, 2006-2015	R2 & Li6262, R3 & Li70000
FI-Hyy	1996-2017	R2 & Li6262
FI-Sii	2005-2015	metek USA-1 & Li7000
FR-Bil	2011-2015	R3-100 & Li7500A
FR-Pue	2001-2014	R3-100 & Li6262

In addition to the two sites per partner, the Belgian site BE-Lon has been added to the dataset (also to increase the number of sites with short vegetation). The metadata has been collected and formatted in order to run the processing. All the data are now uploaded in a common RINGO repository in fileshare ready for the processing. The data (1.8 Tb) are in this way also safely stored also for future reprocessing.

In order to better evaluate the differences and potential biases between different setups and processing schemes a comparison has been performed for periods where both the system (pre-ICOS and ICOS) were present. The results are presented in the Milestone MS30 delivered in October 2019 (see one example of the results in Figure 37 below). These results have also been presented by Sabbatini et al. at the AmeriFlux2019 Annual meeting to show the importance of standardization in large networks and at the FLUXCOURSE 2019.

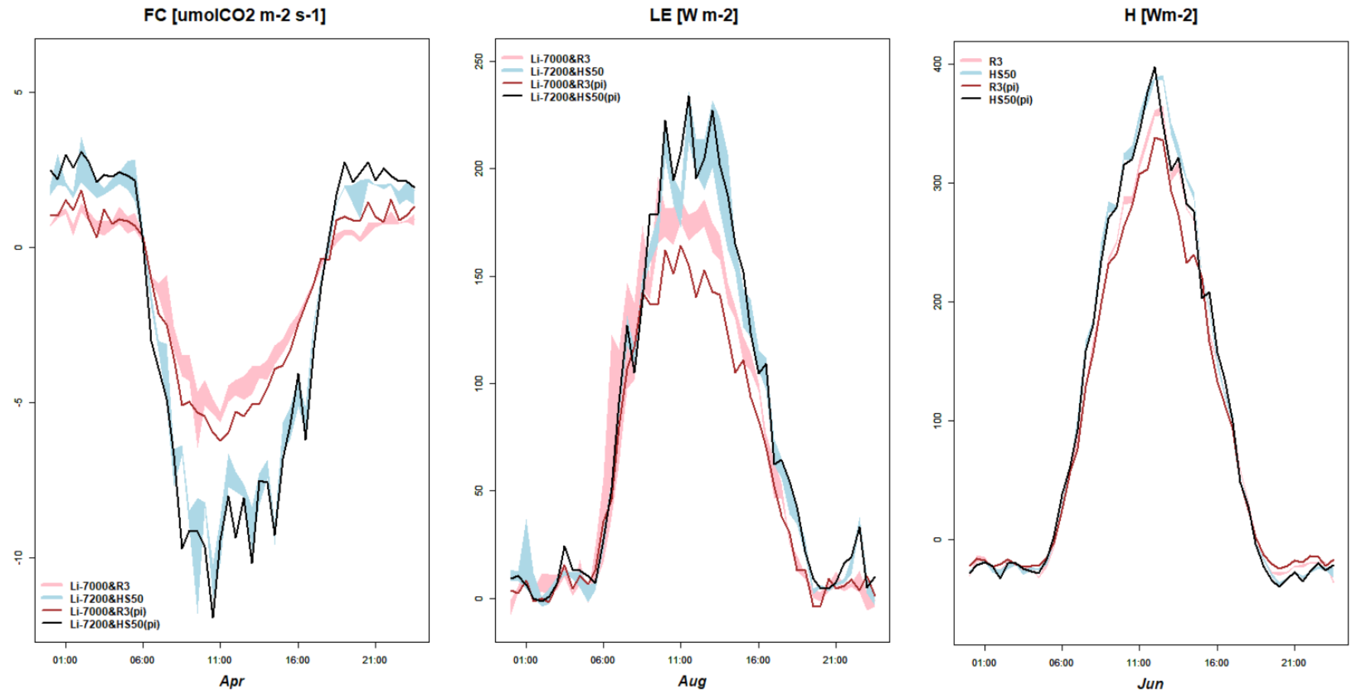


Figure 37. Example of the results presented in the MS30: comparison between ICOS and pre-ICOS (both system and processing) for the three fluxes. Shadow area is the uncertainty in the ICOS processing.

An additional but important activity that has been decided to perform is the preparation of a code to convert the different formats for the legacy data in a standard to be processed with the ICOS methodology. This, in fact, would have multiple benefits: first, the original raw data are not touched, and this increase the safety in particular respect to possible bugs during the conversion. Second, the code can be applied to additional sites in the future in order to apply a common reprocessing. Third, it opens the applicability of the ICOS method also outside the ICOS domain. The code is available on GitHub (https://github.com/icos-etc/EC-Flux-nonICOS), and it is linked to the RFlux library (also on GitHub). At the time of preparation of the report, the codes for the processing are all ready and deployed on GitHub, and as soon as it will be possible to run them on the ICOS cluster, the data will be processed and results provided.

Significant results:

Long term raw data collected from 9 stations and stored safety and ready for processing thanks to an ad-hoc code prepared to apply easily the ICOS processing to different raw data formats.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

The Deliverable D4.3 is late with respect to the prevision. This is due to the amount of work needed for the data collection and transfer and the metadata preparation. However, all is ready for processing, data preparation, and release.

Partner: 1-ICOS ERIC

Description of work carried out in T4.2 by beneficiary

Significant results:

None yet

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

Publication of the datasets is postponed until they are delivered by the TCs

Partner: 3-UNITUSINRA

Description of work carried out in T4.2 by beneficiary

The partner prepared and submitted legacy raw data and metadata for two sites (FR-Bil and FR-Pue)

Partner: 5-UHEI

Description of work carried out in T4.2 by beneficiary

Beneficiary 5-UHEI contributed to MS 36 and D4.2 by delivering all data for the continuous CO_2 record from Heidelberg (ICOS pilot station).

Significant results:

Hourly data from Jan 1st 1996 to December 31st 2017, were delivered.

Deviations from the DoA and/or the planned use of resources; reasons for deviations and the proposed corrective actions

Reassessed Schauinsland CO_2 data from the gas chromatographic system could not be delivered in time as their detailed inspection and comparison with a second continuous CO_2 data set (from an NDIR system) showed significant deviations. There were also systematic deviations of primary standard measurements at the GC system observed, which require a more detailed investigation of all raw data. This work will be conducted when the Schauinsland station PI is back from a sabbatical (February 2020).

Partner: 6-UVGZ

Description of work carried out in T4.2 by beneficiary

Beneficiary 6-UVGZ contributed to D4.3. and MS46 by delivering eddy covariance raw data from two sites – CZ-BK1 and CZ-wet. Also, all necessary metadata, meteorological data, and other information needed were provided. Raw data from pre-ICOS instrument setup was converted from binary format first. UVGZ participated in the related WP4 meeting organised in RINGO 3rd Annual Meeting.

Significant results:

Site CZ-BK1: raw data from the period 2005-2018 was delivered.

Site CZ-wet: raw data from the period 2006-2018 was delivered.

The partner prepared and submitted legacy raw data and metadata for two sites (CZ-BK1 and CZ-wet).

Partner: 11-ETHZEMPA

Description of work carried out in T4.2 by beneficiary

Beneficiary 11-ETHZEMPA contributed to D4.2. by providing historic CO2 data from Jungfraujoch, providing respective metadata and quality control information, by reviewing the data products produced by the lead beneficiary and by contributing to the discussions how to best harmonize the reprocessing of the historic data for the whole set of different stations and how to systematically determine measurement uncertainties based on the available information.
Beneficiary 11-ETHZEMPA contributed to Milestone MS36, MS45 by closely collaborating with the lead beneficiaries to provide all required information.

Significant results:

Harmonized reprocessed CO2 dataset.

Partner: 7-RUG

Description of work carried out in T4.2 by beneficiary

Beneficiary 7-RUG contributed to D4.2 and Milestones MS36 and MS45 by quality assurance/quality control of historical CO2 data at Lutjewad from 2006 to 2017, prior to the official ICOS data starting 2018. RUG sent the recalibrated cylinder values and other metadata to ATC.

Significant results:

The historical data from 2006 to 2017 and 2018 ICOS data were used in the 2018 drought studies, and are also published in the recent ObsPack product.

Partner: 7-RUGECN

Description of work carried out in T4.2 by beneficiary:

Beneficiary 7-RUGECN became part of the TNO organization in 2018 and contributed to D4.2 and Milestones MS36 and MS45 by providing the quality assurance/quality control of historical CO2 data at Cabauw station from 1992 to 2018.

Significant results:

The historical data from 1992 to 2018 data were used in the 2018 drought studies, and are also published in the recent Obspack product.

Partner: 27. DWD

Description of work carried out in T4.2 by beneficiary:

The partner prepared and submitted legacy raw data and metadata for two sites (DE-Geb and DE-Tha). DWD contributed to Subtask 4.2.2 by making data from two long-term eddy covariance sites available, which are run by national ICOS consortium partners of DWD in Germany.

For the agricultural ecosystem site DE-Geb, eddy covariance raw data measured at 20 Hz with a Gill-Solent-R3/LI-6262 system, half-hourly meteorological variables, metadata and PI-processed versions of eddy covariance CO_2 flux data were delivered and completely documented. The data had to be re-organised using a format that was developed and made available for this task by ICOS-ETC. Both legacy data from 2001 to 2017 and ICOS data from 2016 to 2018 were delivered. This enabled a comparison of the results from the two different setups for the year 2017, as agreed upon at the start of the project. The data set provided was included in the 2018 drought analysis, as mentioned elsewhere in the report.

For the DE-Tha forest site, eddy covariance raw data measured from 1997 to 2006 at 20 Hz with a Gill-Solent-R2/LI-6262 system and from 2006 to 2018 at 25 Hz with a Gill-Solent-R3/LI-7000 system were submitted. The latter setup is still running alongside the ICOS system (Gill-HS-50/LI-7200), for which 20 Hz raw data from 2016 to 2018 were used in this project task. Metadata (including the methods of quality checks) and half-hourly meteorological driving variables for the entire period 1997 to 2018 were submitted as well and made available for RINGO. The legacy raw data were re-processed using the EddyPro software (versions 6.0.0 and 6.2.0), however, an upload of the resulting fluxes has not yet been requested.

Data preparation and upload followed an agreement with Sundas Shaukat in order to make the data comparable with those from other sites. Further data analysis, based on all contributing sites and following the Description of Work, was carried out by the other project partners. Thus, in terms of the main results of this subtask, according to Deliverable 4.3, we refer to the summarising report for task 4.2.

Partner: 9-UHEL
Description of work carried out in T4.2 by beneficiary:
Beneficiary 9-UHEL has prepared and submitted legacy raw data and metadata for two sites (FI-Hyy and FI-Sii)

Partner: 9-UHELFMI
Description of work carried out in T4.2 by beneficiary:
Beneficiary 9-UHELFMI contributed to D4.2. by producing metadata and provided CO2 time series of Pallas station.
Beneficiary 9-UHELFMI contributed to Milestone MS36 by producing metadata and provided CO2 time series of Pallas station.

Partner: 14-OMSZ
Description of work carried out in T4.2 by beneficiary
OMSZ has provided all data and relevant background information, including metadata for the joint activity in the framework of Task 4.2.

Work Package 5: Towards a Global Carbon and GHG observation system

Summary

While the concept of the global network of cooperation with key actors has been discussed, coming into an MoU (if this is deemed to be the proper way forward with all the actors) still requires further discussions, which is expected to go even beyond the duration of the project. However, significant steps forward have been achieved. The Carbon Portal of ICOS ERIC has been active in participating and coordinating actions. The Director of Carbon Portal has participated in several WMO GAW and IG3IS meetings, and the Carbon Portal and ULUND hosted a IG3IS/Transcom meeting in Lund 2018 attended by nearly 100 scientists and contributed to the follow-up meeting in Paris 2019. Also, discussions have started with the World Data Center for Greenhouse Gases on the automatic ICOS data flow into the global database.

Significant advances have also been made with the ICOS Thematic Centers becoming operational pillars for global networks. Currently, data from ocean domain, SOCAT, and GLODAP, is handled at one point by UiB making UiB and ICOS OTC a global key player and elementary part of these data products. NERCUEA has supported OTC in regards to SOCAT, as well as coordinated the public release of SOCATv2019. In addition, the respective websites for GLODAP (www.glodap.info) and SOCAT (www.socat.info) were established, updated, are being maintained and hosted by ICOS OTC partner UiB. UNITUS made progress with ecosystem domain by releasing a common processing tool applied by large networks, by formulizing agreements with AmeriFlux and NEON about harmonization of standards, licence and metadata, and by supporting the open access release of data from over 200 stations. UVSQ progressed within the atmosphere domain by contributing to IG3IS with CO2-low-cost-sensor tests in and around cities, by gathering the most extensive CO2 dataset over Europe, and by advancing measurement techniques in international meetings.

List of deliverables due to be completed within this task within this reporting period:
D5.2 GLODAP and SOCAT services fully implemented at OTC (M30)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS37	Global network of cooperation finalized	**WP5**	1 - ICOS ERIC	24	Global network of cooperation finalized
MS47	GLODAP and SOCAT services fully implemented at OTC	**WP5**	2 - UiB	30	GLODAP and SOCAT services fully implemented at OTC

Contributions per task:

Task 5.1: Building stable cooperation with other regional observational networks

Task leader: ICOS ERIC (6)

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS37	Global network of cooperation finalized	**WP5**	1 - ICOS ERIC	24	Global network of cooperation finalized

Partner: 1-ICOS ERIC

Description of work carried out in T5.1 by beneficiary

Beneficiary (1) ICOS ERIC contributed to Milestone MS37:

Task 5.1 The ICOS Carbon Portal director is part of the IG3IS executive committee and attended several workshops and meetings related to IG3IS and GAW, for example, the two-yearly WMO GAW Scientific Steering Committee meeting that this time was related to the WMO reorganisation and the consequences for GAW and IG3IS. In September 2018, ICOS Carbon Portal hosted the very successful IG3IS/Transcom meeting in Lund, which was attended by just under 100 scientists. A follow-up meeting was organised in September 2019 in Paris. In both meetings, ICOS CP presented progress and results of ICOS, including development of elaborated products and the use of Jupyter notebooks by the community, for example in the EUROCOM flux inversion synthesis, the Global Carbon Project and Drought-2018 initiative.

Further integration of ICOS data into the NOAA/ICOS Globalview Obspack products was established, including automatic data usage tracking at ICOS CP for every download of ObsPack products that contains ICOS data for these datasets.

CP Director also took part in the Expert Team (ET-WDC) for the WMO GAW World Data Centers where the progress of implementing the WMO WIGOS and WIS systems are discussed. At the 20th WMO/IAEA meeting in September 2019 in Jeju, South Korea, CP chaired the session and meeting report chapter on data management and presented an outlook for an improved and more FAIR (meta)data handling system of WMO GAW for greenhouse gas data.

Discussions have started with the WMO GAW World Data Center for Greenhouse Gases on how to streamline the automatic flow of ICOS atmosphere Level 2 products into the global database. However, this is a very slow process.

Significant results:

Successful IG3IS/Transcom workshop organised in Lund. ICOS Atmosphere accepted as WMO GAW contributing network.

Task 5.2: Developing ICOS Thematic Centers as stable operational pillars for domain-specific global networks

Task leader: UiB (16), Participants: ULUND (2), UNITUS (6), UVSQ (6), NERCUEA (4)

List of deliverables due to be completed within this task within this reporting period:
D5.2 GLODAP and SOCAT services fully implemented at OTC (M30)
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS47	GLODAP and SOCAT services fully implemented at OTC	**WP5**	2 - UiB	30	GLODAP and SOCAT services fully implemented at OTC

Partner: 2-UiB
Description of work carried out in T5.2 by beneficiary
In the second reporting period beneficiary 2-UiB contributed to D5.2. by establishing ICOS OTC towards the European pillar of Global Data Analysis Project (GLODAP) and the Surface Ocean Carbon Dioxide Atlas (SOCAT). The GLODAP and SOCAT provide public access to quality-controlled, harmonised, and integrated global collections of EOV Inorganic Carbon data from the interior and surface ocean. While SOCAT has evolved into a highly automated community effort based on Live Access Server (LAS) on-line documentation, versioning, and QC tools, GLODAP, whose version 2 was released in January 2016, lacks a centralised automated system for data ingestion, documentation and QC. All of these activities are to a large extent, prepared and handled on a per scientist basis. Within RINGO, we proposed to prepare an online system for data ingestion, versioning, quality control, and the merging of individual data files and QC results to actual products, similar to the SOCAT LAS and automation system. This will enable GLODAP to evolve into a routine interior ocean synthesis, with new versions released every year. The automated system can also handle data (including generic quality control) that is currently not handled systematically within GLODAP or SOCAT e.g. data from discrete sampled coastal data from research vessels and fixed ocean time series stations. Partner UiB has also supported data management activities for past versions of SOCAT. The developments for GLODAP and for SOCAT made ICOS visible to international marine biogeochemistry, and there is no doubt that the data management infrastructure of ICOS OTC is a global and the main European key player for these.
Significant results:
Currently, all of the above data from SOCAT and GLODAP is handled at one point by UiB, making UiB and ICOS OTC a global key player and elementary part of these data products. In addition, the respective websites for GLODAP (www.glodap.info) and SOCAT (www.socat.info) were established, updated, are being maintained and hosted by ICOS OTC partner UiB.

Partner: 3-UNITUS
Description of work carried out in T5.2 by beneficiary
In this second period, the activities to build a more robust global network with the TC as pillar continued with discussions and agreements in the context of FLUXNET. In particular, the following activities have been completed or developed:

1) A common processing tool has been released, and it is publically available in GitHub (https://github.com/icos-etc/ONEFlux). This tool is applied by both the large networks making the data fully standardized. The resource is also used as an example and motivation for the other networks to join practically a common harmonization strategy.
2) The FLUXNET integration has been discussed in depth (in particular the critical points) with the major regional networks, during a specific AGU2019 session (where also a poster on the topic has been presented) and at the meetings organized by the regional networks, in particular at the AmeriFlux2019 and AsiaFlux2019 meetings (where also representatives of Australia were present). Additional discussion on the harmonization of standards, licence and metadata with AmeriFlux and NEON during specific working meetings in July 2019 led to an important step forward and agreements for common developments to be achieved in 2020. Results of the discussions were positive, and there is the general intention to arrive by the end of RINGO to an agreement on a new structure of the FLUXNET mechanism where the Regional Networks will play a more strong role in sustaining the global network. This is also confirmed by the point 3 here below.

3) For the first time, a large set of ecosystem sites globally (206 stations, from all the continents) agreed to release their data under a common open data policy (Creative Common CC-BY4). This has been done in the context of a FLUXNET data paper in submission, where the concept of the global harmonized network has been further developed together with the importance of the metadata.

Significant results:
A standard set of tools shared and used between AmeriFlux and ICOS has been released on GitHub (ONEFlux)

Partner: 4-UVSQ
Contributing to the Integrated Global Greenhouse Gas Information System thematic, ATC tested low-cost sensors that could be deployed in and around cities that as a whole represent 70% of CO2 global emissions. Cities have good potential to reduce emissions, and atmospheric data can help monitor emission reduction. The lower cost of the instrument is usually not compatible with a very stable measured signal in time. To account for instrument drifts, innovative calibration strategies are being developed.

In an international European effort, the ATC coordinated the gathering of the most extensive CO2 dataset (48 stations) over Europe. It was used to investigate the effect of the European 2018 drought on the carbon cycle. The long time series could put the extreme event of 2018 in perspective. The first analysis showed that the 2018 drought atmospheric signal was smaller than the one from the 2003 renowned drought over Europe.

ATC gave a plenary talk at the 20th WMO/IAEA meeting on CO2 and other greenhouse gases and related measurement techniques (GGMT2020) in Sept 2019 in Jeju, South Korea. It described the second official ICOS atmospheric data release, the largest GHG integrated data release in the world, contributing to the global WMO GAW network. Prior to this release, the ICOS atmosphere stations have gone through 13 steps labelling process coordinated by the ATC that includes: station geographical situation inspection, internal training, calibration procedure, data flagging tools, and measurement optimisation.

At this GGMT2020 meeting, a new WMO CO2 scale was proposed. It is approximately 0.004% greater than X2007 scale with a nonlinear signal due to the behaviour of the NOAA NDIR instrument in charge of the WMO scale. ICOS and, in particular, the ATC were chosen to prototype the scale change before spreading it to the international community. A working group involving NOAA, ICOS CAL, and ATC was put into place to implement this CO2 scale change. Also, ICOS and NOAA will create a data processing notebook to compare their approach to data processing chain from raw data into correctly calibrated data, including the generation of uncertainty and bias estimates and provenance metadata.

Partner: 8-NERCUEA
Description of work carried out in T5.2 by beneficiary
Task 5.2 Beneficiary 8-NERCUEA has contributed to the development of the Ocean Thematic Center as the European pillar of SOCAT providing core services for this data network. Specifically, UEA has coordinated the public release of SOCATv2019 on 18 June 2019 (www.socat.info) and is coordinating data submission for SOCATv2020 by 15 January 2020. UEA has presented SOCAT and GLODAP at national and international conferences and workshops. UEA has contributed to discussions on data archiving, data access, and data synthesis on the WCRP Data Advisory Council (WDAC). UEA has participated in discussions on a research strategy for ocean carbon research for the coming decade during the IOCR (International Ocean Carbon Research) meeting at IOC UNESCO on 28 to 30 October 2019.
Beneficiary 8-NERCUEA contributed to Milestone MS47 by coordinating the public release of SOCAT version 6 in 2018 and SOCATv2019 in 2019.
Significant results:
SOCAT version 6 in 2018 and SOCATv2019 in 2019

Partner: 10-ULUND
Description of work carried out in T5.2 by beneficiary

Task 5.2 Beneficiary 10-ULUND has contributed to this task through hosting and organising the very successful IG3IS/Transcom meeting in Lund, September 2018, that was attended by just under 100 scientists. A follow-up meeting was organised in September this year in Paris. In both meetings, ICOS CP presented progress and results of ICOS, including development of elaborated products and the use of Jupyter notebooks by the community, for example in the EUROCOM flux inversion synthesis, the Global Carbon Project and Drought-2018 initiative.
Further integration of ICOS data into the NOAA/ICOS Globalview ObsPack products was established, including automatic data usage tracking at ICOS CP for every download of ObsPack products that contains ICOS data for these datasets.
Significant results:
Organising and managing the 2018 IG3IS/Transcom meeting.

Work Package 6: Management

Lead Beneficiary: 1 - ICOS ERIC

Summary

Work Package 6 is responsible for the day-to-day running of the project. The main objectives of WP6 are:

- Concentrating on day-to-day management activities of the project
- Being responsible for project internal coordination structure, financial and administrative management, governance, project reporting coordination and risk management

During the second reporting period, WP6 has produced the final versions of the project's Risk Management Plan, Dissemination Strategy, and Data Management Plan. The Annual Project Meeting was organised in March 2019 in Southampton, including the RINGO General Assembly. The coordination team has also organised bi-monthly Executive Board meetings to check the project's progress, as well as individual teleconferences with each Task Leader to provide a platform for a more detailed discussion about practical matters. The WP has also produced a project handbook that guides the consortium on all practical matters.
The mention of the ICOS ERIC Head Office in the WP6 tasks' descriptions (also in the GA) appoints the tasks performing entity of the ICOS ERIC, as a project coordination team is situated in the ICOS ERIC Head Office.

List of deliverables due to be completed within this WP within this reporting period:
D6.11: Final Dissemination Strategy [36]
D6.12: Final Data Management Plan [36]
List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS57	Final Risk Management Plan	**WP6**	1 - ICOS ERIC	36	Final Risk Management Plan
MS55	Final Dissemination Strategy	**WP6**	1 - ICOS ERIC	36	Final Dissemination Strategy
MS56	Final Data Management Plan	**WP6**	1 - ICOS ERIC	36	Final Data Management Plan

Contributions per task:

Task 6.1: Project financial and administrative management

Task leader: ICOS ERICHO (9)

Description of work carried out in T6.1 by beneficiary
ICOS ERIC contributed by collecting information from the consortium, coordinating financial and technical reporting and communicating with EC, compiling and submitting the report to the EC.
Significant results:
Submitting Periodic Report 2 in time

Task 6.2: Project scientific and progress management
Task leader: ICOS ERICHO (3)

List of deliverables due to be completed within this task within this reporting period:
D6.13 Final Risk Management Plan
List of milestones due to be completed within this task within this reporting period:

MS57	Final Risk Management Plan	**WP6**	1 - ICOS ERIC	36	Final Risk Management Plan

Description of work carried out in T6.2 by beneficiary
Partner: 1-ICOS ERIC
Beneficiary (1) ICOS ERIC contributed to D6.13 by writing the deliverable. The project risk management plan was updated to address any occurrences that were identified as materialised or potential risks during the reporting period 2, with applied and proposed mitigation methods.
The main point addressed is the fact that as the consortium starts working on their allocated tasks at varying intervals (e.g. not everybody starts work simultaneously) it is important to distribute guidelines on H2020 on regular intervals. It is also noted that the work is likely to progress along a different timeline from that of originally proposed in the DoA, meaning that regular updates are needed.
Beneficiary (1) ICOS ERIC contributed to Milestone MS57 by collecting relevant information from the consortium for D6.13

Task 6.3: Project internal communications

Task leader: ICOS ERICHO (3)

List of deliverables due to be completed within this task within this reporting period:
D6.11: Final Dissemination Strategy [36]

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS55	Final Dissemination Strategy	**WP6**	1 - ICOS ERIC	36	Final Dissemination Strategy

Description of work carried out in T6.3 by beneficiary
Beneficiary (1) ICOS ERIC contributed to D6.11 by compiling the document and collecting information from the consortium, writing the document. The project dissemination strategy was updated to reflect the dissemination events carried out during reporting period 2.
Beneficiary (1) ICOS ERIC contributed to Milestones MS55 by compiling the contents for the document
Significant results:
Finalising the Dissemination Plan

Task 6.4: Organization of data management
Task leader: ICOS ERICHO (3)

List of deliverables due to be completed within this task within this reporting period:
D6.12: Final Data Management Plan [36]

List of milestones due to be completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS56	Final Data Management Plan	**WP6**	1 - ICOS ERIC	36	Final Data Management Plan

Partner: 1-ICOS ERIC
Description of work carried out in T6.4 by beneficiary
Beneficiary (1) ICOS ERIC contributed to D6.12 by writing the deliverable. The project data management plan has been developed during the first six months of the project and show the close connection to the ICOS RI operational data management. It is envisaged that the data obtained in the framework of the RINGO project will be published under the same conditions as ICOS data. ICOS has decided to use the Creative Commons 4.0 BY license that ensures open and free data access. The final data management plan includes archiving solutions and the minting of Datacite DOIs including management of the required metadata for data citation of the RINGO (collections of) data products**.**
Beneficiary (1) ICOS ERIC contributed to Milestone MS56 by compiling the document.
Significant results: Final Data Management Plan

5. Update of the plan for exploitation and dissemination of results

We presented the latest dissemination and exploitation strategy and results in D6.11 (Final Dissemination Plan). This version included updates to dissemination activities and channels executed and utilised so far in the project, with heightened attention to the GDPR regulation. RINGO acknowledges the regulation and is taking the necessary actions to ensure compliance with it in all its dissemination activities. The final Dissemination Plan also pooled together results disseminated so far in the project.

Dissemination and Exploitation activities in RINGO between 1.1.2017-30.6.2018

RINGO news and events	News article 'Study reveals how environmental impacts on European ecosystems can be monitored more accurately', October 2019	Global		
RINGO news and events	News article 'Transfer of knowledge at RINGO Summer School', October 2019	Global		
RINGO news and events	News article 'AirCore campaign visits ICOS Trainou site', July 2019	Global		
ICOS news	News article 'ICOS Handbook published', May 2019	Global		
RINGO news and events	News article 'ICOS Marine Monitoring Station Assembly', March 2019	Global		
RINGO news and events	News article 'ICOS Symposium on the North Atlantic Carbon Cycle', March 2019	Global		
RINGO news and events	News article 'ICOS Ocean Thematic Centre Industry–Science Observing Forum', March 2019	Global		
ICOS Newsletter 10/2019	News article 'Study reveals how environmental impacts on European ecosystems can be monitored more accurately', October 2019	Global		
ICOS Community News 10/2019	News article 'Study reveals how environmental impacts on European ecosystems can be monitored more accurately', October 2019	ICOS community		
ICOS Community News 7/2019	News article 'AirCore campaign at ICOS Trainou site', July 2019	ICOS community		
ICOS Newsletter 7/2019	News article 'AirCore campaign visits ICOS Trainou site', July 2019	Global		
ICOS Community News 5/2019	News article 'First ICOS Handbook published', May 2019	ICOS community		
ICOS Newsletter 5/2019	News article 'ICOS Handbook published', May 2019	Global		
ICOS Community News 2/2019	News article 'ICOS Handbook in the making', February 2019	ICOS community		
ICOS Community News 1/2019	News article 'Several events organised around the RINGO Annual Meeting', January 2019	ICOS community		
ICOS Newsletter 1/2019	News article 'ICOS Symposium on the North Atlantic Carbon Cycle', January 2019	Global		
ICOS Newsletter 1/2019	News article 'Joint event for shipping industry & ocean community', January 2019	Global		
ICOS Community News 12/2018	News article 'Events: RINGO'	ICOS community		
ICOS Newsletter 7/2018	News article 'Save the date: RINGO Annual meeting', October 2018	Global		

Conwy Catchment workshop	WP1	8 NERC	24	Conwy Catchment workshop held
Hyytiälä Forestry Field Station workshop	WP1	9 - UHEL	30	Hyytiälä, Finland at the Hyytiälä Research Station, hosted by the University of Helsinki from 5th to 8thNovember, 2019.
TCCON and ICOS data integration workshop				Prague 2018
TCCON and ICOS data integration workshop	WP 5	4-UVSQ		Southampton, UK, the National Oceanography Centre, 20-22 March 2019
Two workshops for eddy covariance users in Portugal	WP2	6- UVGZ	n/a	Portugal, July 23 2019 and, December 5, 2019.
Second summer school providing scientific training for new countries	WP2	6 - UVGZ	36	Ostrava, CZ, 6.11.2018
'Improving European Charter of Access to Research Infrastructures from the perspective of responsible research and innovation approach' Workshop, Research and Innovation Days	WP2	6 - UVGZ	n/a	Brussels, BE, 25.9.2019 https://ec.europa.eu/info/research-and-innovation/events/upcoming-events/european-research-and-innovation-days_en
10th Danube Academies Conference	WP2	6 - UVGZ	n/a	Prague, CZ, 31.10.2019 https://www.euro-acad.eu/events?id=41
International workshop on enhancing ICOS Ecosystem sites to become sentinel sites in cooperation with other domain-specific ESFRI and global infrastructure	WP3	3-UNITUS	24	
2nd International COS workshop	WP3	4 -UVSQ	n/a	Obergurgl University Center, Austria, November 2019. http://www.biomet.co.at/2nd-international-cos-workshop/
IG3IS/Transcom workshop	WP5	1-ICOS ERIC		Lund, 17-20. September 2018 https://www.icos-cp.eu/TRANSCOM_IG3IS_meeting
3rd International ICOS Science Conference	WP1-6	All	n/a	Prague 11.9.-14.9.2018 https://conference.icos-ri.eu/
A conference on "TLS in forest ecology - expanding the horizon"	WP1	12-UAnt	n/a	Gent, Belgium, May 6.-7.2019 . www.tlsforest2019.ugent.be/
2019 Joint Satellite Conference	WP3			28 September - 4 October 2019, Westin Waterfront, Boston, MA
Fourier Transform Spectrometer measurements of column CO_2 and CH_4 at Sodankylä, Geophysical Research Abstracts, Vol. 21.	WP3	9-UHEL_FMI	n/a	EGU 2019, Vienna, Austria | 7–12 April 2019 https://www.egu2019.eu/
2019 Oceanobs conference	WP3			16-20 September 2019 Hawaii/USA http://www.oceanobs19.net/
the IOCR (International Ocean Carbon Research) meeting	WP5			IOC UNESCO 28 to 30 October 2019. https://www.oceanexpert.net/event/2564
The 15th International Workshop on Greenhouse	WP3	UHEL_FMI	n/a	(IWGGMS-15), June 3rd - 5th, 2019, Hokkaido University, Sapporo, Japan, 2019

Gas Measurements from Space				https://www.nies.go.jp/soc/en/events/iwggms15/
IUFRO international workshop	WP3	UNITUS_INRA	n/a	29 sept - 5 October 2019, Curitiba, PR, Brazil https://www.iufro.org/science/special/spdc/tw/

Published Deliverables 1.7.2018-31.12.2019

WP No	Del No	Title	Nature	Dissemination Level
WP1	D1	Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs.	Report	Public
WP1	D3	An ICOS flask sampling protocol based on historical time series and high resolution footprint modelling.	Report	Public
WP1	D4	Report describing the ideal and minimum requirements of an aquatic transport and fluxes observation system including possible role of ICOS RI and resulting costs to be presented to EC, ESFRI and ICOS General Assembly.	Report	Public
WP1	D5	Scientific-technical concept for the integration of European TCCON sites into ICOS and resulting costs.	Report	Public
WP1	D6	Ocean-atmosphere flux NRT data calculation routine including satellite data streams on surface temperature, skin effects, wave state and wind speeds.	Demonstrator	Public
WP3	D17	Protocol for non-CO2 eddy covariance measurements, QA/QC, data processing and gap-filling.	Report	Public
WP4	D20	Ambient CO2 time series for the selected 10 measurement stations covering the period 2000-2015.	ORDP: Open Research Data Pilot	Public
WP6	D34	First Updated Risk Management Plan	Report	Public
WP6	D36	Periodic Report 2 including request for second interim payment	Report	Public
WP6	D37	Final Dissemination Strategy	Report	Public
WP6	D38	Final Data Management Plan	Report	Public

6. Update of the data management plan

The updated Data Management Plan has been constructed based on the FAIR principle: Findable, Accessible, Interoperable, and Reusable. Since each community follows its own conventions in file naming, it is crucial to that we maintain descriptions in the data content ontology (data columns, variables, units) to fulfil the first requirement Findable, prior assigning all of the data objects at ingestion a Persistent Identifier (PID) based on the handle system. The second requirement will be met by making all of the data is made open via the (CP) Carbon Portal, first to project participants only until the end of the RINGO program but released, providing open access according to ICOS Data Policy once the project has ended. The third requirement interoperability can only be defined in relation to an actual implementation and solution. The plan is to support all relevant standard vocabularies by mapping the ontologies to the ICOS standard dynamically. Reusability ICOS being a long-term infrastructure that is foreseen to exist for at least 20-25 years. This would guarantee operation and data availability until 2040. All data that falls under the CC4BY licence is available to all third parties. Albeit of RINGO experimental data results, which are restricted to the consortium until the end of the project, but they will become available within 2 years from the end of the project.
Final Data Management Plan further defined the processes and details.

7. Deviations from Annex 1 and Annex 2

Explain the reasons for deviations from the DoA, the consequences and the proposed corrective actions
Tasks

The following deviations to tasks from Annex 1 and 2 happened during this reporting period:

WP1

Task 1.1

The work in Task 1.1.has been extended to PR2 during the course of the project in order to harmonise it with the ESFRI process of developing a monitoring concept for Landmark Research Infrastructures. There has been an intense exchange with the respective ESFRI working group. In order to continue this exchange, it is foreseen that a few remaining resources (< 1PM) will be allocated to Task 1.1 even after the submission of the deliverable D1.1.

Task 1.4

D1.4

The completed Deliverable report has been delayed and is planned to be finalised by May 2020. This delay is caused due to the fact that to complete the work required altogether 3 different workshops. These had to be rescheduled, which also caused a delay due to participants' sea-going commitments. The workshops are completed and during these events, a working draft of the report has been compiled. It is constructed by 40 authors that have contributed to the work, which is, therefore, causing this unexpected delay.

WP3

Task 3.2

D3.2

As outlined in the first periodic report, the start of construction was delayed because of late entering as a beneficiary into the project and late availability of the sensor. Most importantly, however, the unforeseen decision of the shipping company (Finnlines) of not allowing the installation on SOOP Finnmaid, despite earlier positive evaluation and the fact that IOW maintains pCO2 installation on this ship since 2003, now as part of ICOS, lead to the necessity to find a new ship of operation. This problem was solved. The deviations from the original planning is limited to the time line towards fulfilling the deliverables/milestones. No change in the use of resources.

Task 3.4

D3.4

The completed Deliverable report has been delayed and is planned to be finalised by March 2020. Whilst objectives have been reached, issues with obtaining a suitable vessel in which to test the instrument occurred. Plans to test and integrate the instrument into a vessel (Autonaut) from the National Oceanography Centre met with delays. Currently, tests on an alternative vessel (waveglider) have been scheduled for March 2020.

Task 3.5

D3.5

The completed Deliverable report has been delayed and is planned to be finalised by June 2020. Task 3.5 has been progressing smoothly and without major problems. A network performance analysis has been achieved and presented at the IUFRO international workshop. There are plans to submit a paper about this topic shortly. The upcoming 20-year scenario of climate of pollutants deposition on European ecosystems have been constructed in collaboration with CNRM team (B. Josse) using the chemistry transport model MOCAGE. Examination into how well a station network may detect and attribute the expected climate and pollutants impacts across Europe from 2020 to 2040 is now underway. In addition, contacts were made with other infrastructure through the ENVRI FAIR project and collaboration will continue in February-March to elaborate together with the roadmap to optimise observations on ecosystems in Europe. Therefore, because the maternity leave of the main scientist recruited in this task has stopped the work programme for 5 months altogether, delaying this Deliverable will allow a proper concertation with companion infrastructure to be organised following the next project Workshop (March 2020).

Task3.5

MS35

This MS will be finalised as a side event to ICOS science conference

WP4
Task 4.2
The completed Deliverable report is late with respect to the prevision. This is due to the amount of work needed for the data collection and transfer and the metadata preparation. However all is ready for data preparation and release. Deliverable is expected to be completed by March 2020.

Use of resources:

	WP1	WP2	WP3	WP4	WP5	WP6	Total Person/Months per Participant
1 - ICOS ERIC	7.00	6.00	2.00	3.00	6.00	18.00	42.00
Used PR1	2.12	1.20	0.60	0.31	1.20	11.68	17.11
Used PR2	2,00	5,11	0,16	0,24	1,88	5,06	14,45
Remains	2,88	-0,31	1,24	2,45	2,92	1,26	10,44
2 - UiB	**0.00**	**3.00**	**0.00**	**3.00**	**16.00**	**0.00**	**22.00**
Used PR1	0.00	0.00	0.00	0.00	3.17	0.00	3.17
Used PR2	0.00	0.00	0.00	3.00	14.59	0.00	17.59
Remains	**0.00**	**3.00**	**0.00**	**0.00**	**-1.76**	**0.00**	**1.24**
3 - UNITUS	**0.00**	**4.00**	**4.00**	**15.00**	**6.00**	**0.00**	**29.00**
Used PR1	0.00	0.03	12.40	7.85	1.32	0.00	21.60
Used PR2	0.00	0.06	18.35	14.07	7.35	0.00	39.83
Remains	**0.00**	**3.91**	**-26.75**	**-6.92**	**-2.67**	**0.00**	**-32.43**
· CNR-ISMAR	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.50	0.00	0.00	0.00	0.00	0.00	0.50
Used PR2	0.61	0.00	0.00	0.00	0.00	0.00	0.61
Remains	**-0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.11**
· ENEA	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.13	0.00	0.00	0.00	0.00	0.00	**0.13**
Used PR2	0.24	0.00	0.00	0.00	0.00	0.00	**0.24**
Remains	**0.63**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.63**
· OGS	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.33	0.00	0.00	0.00	0.00	0.00	0.33
Used PR2	0.45	0.00	0.00	0.00	0.00	0.00	0.45
Remains	**0.22**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.22**
· INRA	1.00	0.00	11.00	5.00	0.00	0.00	17.00
Used PR1	0.03	0.00	4.79	0.12	0.00	0.00	4.94
Used PR2	0.34	0.00	16.87	1.22	0.00	0.00	18.43
Remains	**0.63**	**0.00**	**-10.66**	**3.66**	**0.00**	**0.00**	**-6.37**
4 - UVSQ	21.00	4.00	16.00	15.00	6.00	0.00	62.00
Used PR1	13.49	0.00	6.46	6.00	1.05	0.00	27.00
Used PR2	12.17	2.00	27.30	10.00	7.00		58.47
Remains	**-4.66**	**2.00**	**-17.76**	**-1.00**	**-2.05**	**0.00**	**-23.47**

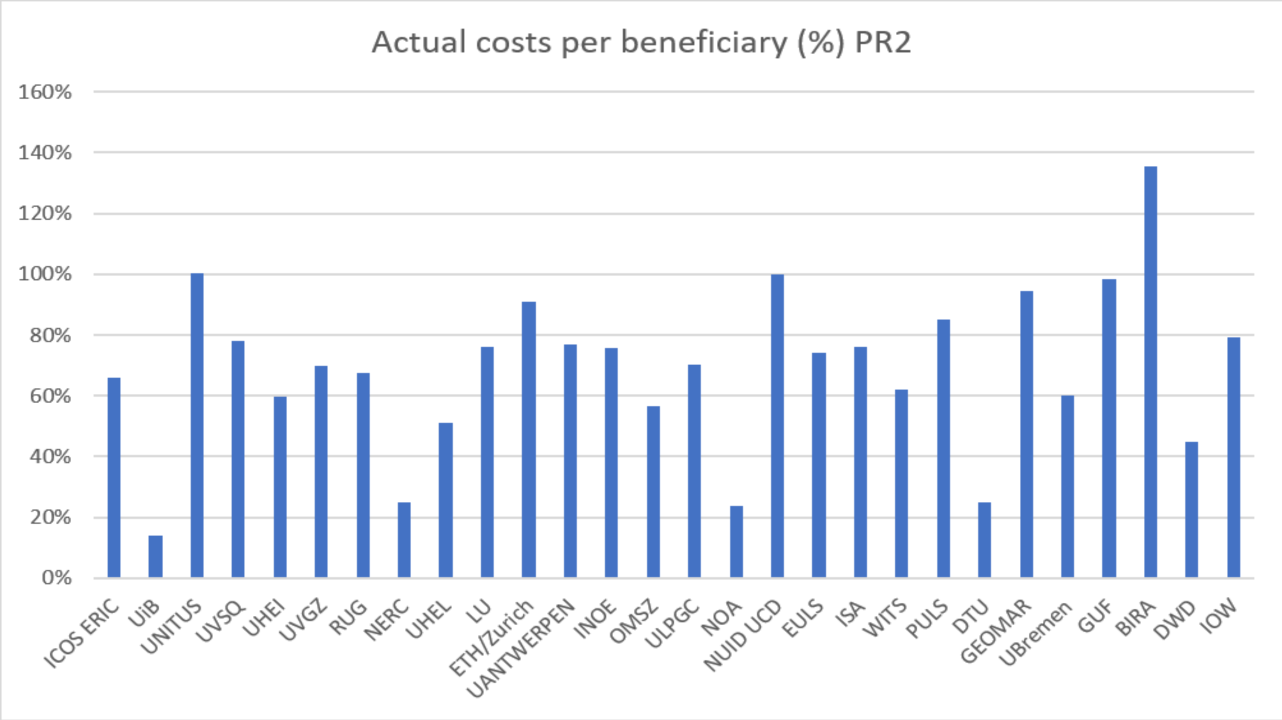
5 - UHEI	14.00	0.00	0.00	5.00	0.00	0.00	19.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	14.35	0.00	0.00	0.00	0.00	0.00	14.35
Remains	**-0.35**	**0.00**	**0.00**	**5.00**	**0.00**	**0.00**	**4.65**
· MPG	0.00	0.00	4.00	0.00	0.00	0.00	4.00
Used PR1	0.00	0.00	3.00	0.00	0.00	0.00	3.00
Used PR2	0.00	0.00	7.00	0.00	0.00	0.00	7.00
Remains	**0.00**	**0.00**	**-6.00**	**0.00**	**0.00**	**0.00**	**-6.00**
6 - UVGZ	0.00	36.00	0.00	5.00	0.00	0.00	41.00
Used PR1	0.00	16.00	0.00	1.80	0.00	0.00	17.80
Used PR2	0.00	24.95	0.00	1.80	0.00	0.00	26.75
Remains	**0.00**	**-4.95**	**0.00**	**1.40**	**0.00**	**0.00**	**-3.55**
7 - RUG	11.00	0.00	6.00	1.00	0.00	0.00	18.00
Used PR1	4.80	0.00	2.40	0.40	0.00	0.00	7.60
Used PR2	3.00	0.00	2.21	0.37	0.00	0.00	5.58
Remains	**3.20**	**0.00**	**1.39**	**0.23**	**0.00**	**0.00**	**4.82**
· WU	7.00	0.00	0.00	0.00	0.00	0.00	7.00
Used PR1	2.70	0.00	0.00	0.00	0.00	0.00	2.70
Used PR2	3.06	0.00	0.00	0.00	0.00	0.00	3.06
Remains	**1.24**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.24**
· ECN	1.00	0.00	0.00	1.00	0.00	0.00	2.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	1.22	0.00	0.00	1.21	0.00	0.00	2.43
Remains	**-0.22**	**0.00**	**0.00**	**-0.21**	**0.00**	**0.00**	**-0.43**
8 - NERC	9.00	0.00	8.00	0.00	0.00	0.00	17.00
Used	4.81	0.00	1.78	0.00	0.00	0.00	6.59
Remains	**4.19**	**0.00**	**6.22**	**0.00**	**0.00**	**0.00**	**10.41**
· UEA	0.00	0.00	0.00	0.00	4.00	0.00	4.00
Used	0.00	0.00	0.00	0.00	1.92	0.00	1.92
Remains	**0.00**	**0.00**	**0.00**	**0.00**	**2.08**	**0.00**	**2.08**
· UOE	10.00	0.00	8.00	0.00	0.00	0.00	18.00
Used	0.24	0.00	4.27	0.00	0.00	0.00	4.51
Remains	**9.76**	**0.00**	**3.73**	**0.00**	**0.00**	**0.00**	**13.49**
· PML	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	1.00
9 - UHEL	4.00	0.00	8.00	5.00	0.00	0.00	17.00
Used PR1	0.43	0.00	3.00	1.00	0.00	0.00	4.43
Used PR2	0.00	0.00	4.93	4.93	0.00	0.00	9.86
Remains	**3.57**	**0.00**	**0.07**	**-0.93**	**0.00**	**0.00**	**2.71**
· FMI	1.00	0.00	5.00	2.00	0.00	0.00	8.00

Used PR1	0.14	0.00	3.79	0.14	0.00	0.00	4.07
Used PR2	0.05	0.00	1.99	0.14	0.00	0.00	2.18
Remains	**0.81**	**0.00**	**-0.78**	**1.72**	**0.00**	**0.00**	**1.75**
10 - ULUND	8.00	0.00	0.00	15.00	2.00	0.00	25.00
Used PR1	1.53	0.00	0.00	3.06	0.21	0.00	4.80
Used PR2	4.29	0.00	0.00	6.49	0.00	0.00	10.78
Remains	**2.18**	**0.00**	**0.00**	**5.45**	**1.79**	**0.00**	**9.42**
· UGOT	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Remains	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
· UUPP	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	0.52	0.00	0.00	0.00	0.00	0.00	0.52
Remains	**0.48**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.48**
11 - ETH Zürich	0.00	0.00	2.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.00	0.80	0.00	0.00	0.00	0.80
Used PR2	0.00	0.00	4.80	0.00	0.00	0.00	4.80
Remains	**0.00**	**0.00**	**-3.60**	**0.00**	**0.00**	**0.00**	**-3.60**
· UBern	0.00	0.00	2.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**0.00**	**0.00**	**2.00**	**0.00**	**0.00**	**0.00**	**2.00**
· EMPA	0.00	0.00	0.00	3.00	0.00	0.00	3.00
Used PR1	0.00	0.00	0.00	0.54	0.00	0.00	0.54
Used PR2	0.00	0.00	0.00	2.78	0.00	0.00	2.78
Remains	**0.00**	**0.00**	**0.00**	**-0.32**	**0.00**	**0.00**	**-0.32**
12 - UANTWERPEN	12.00	0.00	1.00	0.00	0.00	0.00	13.00
Used PR1	12.00	0.00	0.00	0.00	0.00	0.00	12.00
Used PR2	10.59	0.00	0.61	0.00	0.00	0.00	11.20
Remains	**-10.59**	**0.00**	**0.39**	**0.00**	**0.00**	**0.00**	**-10.20**
· VLIZ	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.00**
13 - INOE	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	1.13	0.00	0.00	0.00	0.00	1.13
Used PR2	0.00	0.97	0.00	0.00	0.00	0.00	0.97
Remains	**0.00**	**-0.10**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.10**
14 - OMSZ	0.00	6.00	0.00	7.00	0.00	0.00	13.00

Used PR1	0.00	1.00	0.00	1.00	0.00	0.00	2.00
Used PR2	0.00	1.00	0.00	1.00	0.00	0.00	2.00
Remains	**0.00**	**4.00**	**0.00**	**5.00**	**0.00**	**0.00**	**9.00**
15 - ULPGC	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.60	0.00	0.00	0.00	0.00	0.60
Used PR2	0.00	1.00	0.00	0.00	0.00	0.00	1.00
Remains	**0.00**	**0.40**	**0.00**	**0.00**	**0.00**	**0.00**	**0.40**
16 - NOA	0.00	4.00	0.00	0.00	0.00	0.00	4.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**0.00**	**4.00**	**0.00**	**0.00**	**0.00**	**0.00**	**4.00**
17 - NUID UCD	0.00	3.00	0.00	0.00	0.00	0.00	3.00
Used PR1	0.00	8.83	0.00	0.00	0.00	0.00	8.83
Used PR2	0.00	0.50	0.00	0.00	0.00	0.00	0.50
Remains	**0.00**	**-6.33**	**0.00**	**0.00**	**0.00**	**0.00**	**-6.33**
18 - EULS	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.40	0.00	0.00	0.00	0.00	0.40
Used PR2	0.00	1.00	0.00	0.00	0.00	0.00	1.00
Remains	**0.00**	**0.60**	**0.00**	**0.00**	**0.00**	**0.00**	**0.60**
19 - ISA	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.87	0.00	0.00	0.00	0.00	0.87
Used PR2	0.00	1.28	0.00	0.00	0.00	0.00	1.28
Remains	**0.00**	**-0.15**	**0.00**	**0.00**	**0.00**	**0.00**	**-0.15**
20 - WITS	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.50	0.00	0.00	0.00	0.00	0.50
Used PR2	0.00	0.51	0.00	0.00	0.00	0.00	0.51
Remains	**0.00**	**0.99**	**0.00**	**0.00**	**0.00**	**0.00**	**0.99**
21 - PULS	0.00	2.00	0.00	0.00	0.00	0.00	2.00
Used PR1	0.00	0.75	0.00	0.00	0.00	0.00	0.75
Used PR2	0.00	1.00	0.00	0.00	0.00	0.00	1.00
Remains	**0.00**	**0.25**	**0.00**	**0.00**	**0.00**	**0.00**	**0.25**
22 - DTU	0.00	0.00	5.00	0.00	0.00	0.00	5.00
Used PR1	0.00	0.00	0.82	0.00	0.00	0.00	0.82
Used PR2	0.00	0.00	1.10	0.00	0.00	0.00	1.10
Remains	**0.00**	**0.00**	**3.08**	**0.00**	**0.00**	**0.00**	**3.08**
23 - GEOMAR	0.00	0.00	8.00	0.00	0.00	0.00	8.00
Used PR1	0.00	0.00	8.00	0.00	0.00	0.00	8.00
Used PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

· IOW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Remains	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
24 - UBremen	8.00	0.00	5.00	0.00	0.00	0.00	13.00
Used PR1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Used PR2	3.74	0.00	3.33	0.00	0.00	0.00	7.07
Remains	**4.26**	**0.00**	**1.67**	**0.00**	**0.00**	**0.00**	**5.93**
25 - GUF	0.00	0.00	5.00	0.00	0.00	0.00	5.00
Used PR1	0.00	0.00	2.40	0.00	0.00	0.00	2.40
Used PR2	0.00	0.00	4.47	0.00	0.00	0.00	4.47
Remains	**0.00**	**0.00**	**-1.87**	**0.00**	**0.00**	**0.00**	**-1.87**
26 - BIRA	4.00	0.00	4.00	0.00	0.00	0.00	8.00
Used PR1	1.54	0.00	2.82	0.00	0.00	0.00	4.36
Used PR2	4.03	0.00	7.93	0.00	0.00	0.00	11.96
Remains	**-1.57**	**0.00**	**-6.75**	**0.00**	**0.00**	**0.00**	**-8.32**
27 - DWD	0.00	0.00	7.00	5.00	0.00	0.00	12.00
Used PR1	0.00	0.00	4.11	1.62	0.00	0.00	5.73
Used PR2	0,00	0,00	2,70	2,10	0,00	0,00	4,80
Remains	**0,00**	**0,00**	**2,89**	**3,38**	**0,00**	**0,00**	**6,27**
28 - IOW	0.00	0.00	9.00	0.00	0.00	0.00	9.00
Used PR1	0.00	0.00	5.00	0.00	0.00	0.00	5.00
Used PR2	0.00	0.00	5.50	0.00	0.00	0.00	5.50
Remains	**0.00**	**0.00**	**-1.50**	**0.00**	**0.00**	**0.00**	**-1.50**
Total Person/Months	**125,00**	**78,00**	**120,00**	**90,00**	**40,00**	**18,00**	**471,00**
PR1 Total Person/Months Used	**44,79**	**31,31**	**66,44**	**23,84**	**8,87**	**11,68**	**186,93**
PR2 Total Person/Months Used	**61,66**	**39,35**	**109,25**	**49,35**	**30,82**	**5,06**	**295,49**
Total Person/Months Remains	**18,55**	**7,34**	**-52,99**	**18,91**	**0,31**	**1,26**	**-6,62**

Actual costs per beneficiary:



Explanations on transfers between cost categories:
N/A

8. Unforeseen subcontracting

Not applicable

9. Unforeseen use of in kind contribution from third party against payment or free of charges

Not applicable