RINGO | Readiness of ICOS

Readiness of ICOS for Necessities of integrated Global Observations

1st Periodic Technical Report Part B

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Readiness of ICOS for Necessities of integrated Global Observations

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Periodic Technical Report
Part B

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Periodic report: [1st]

[10] The term ‘project’ used in this template equates to an ‘action’ in certain other Horizon 2020 documentation

Contents

1. Introduction and executive summary

The Integrated Carbon Observation System (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 provides data for the science to understand the Earth system. Scientific knowledge on carbon emissions, sinks and trends advances the fulfilment of the UN Sustainable Development Goals (Goal 13: Take urgent action to combat climate change and its impacts) and EU Societal Challenges (Climate Action - Informed decisions for a climate-resilient low-carbon society). ICOS' mission to understand the carbon cycle and to provide necessary information on greenhouse gases, places ICOS into a framework of international climate activities. Knowledge generated on the use of ICOS data supports efforts to comply with the Paris Agreement resolutions within the United Nations Framework Convention on Climate Change (UNFCCC). ICOS responds to the international goal to establish global standards for observations as well as open, accessible and interoperable data in order to ensure optimal services for societies in their efforts to mitigate climate change. ICOS is directly responding to the "Essential Climate Variables" (ECVs) developed under the United Nations Framework Convention on Climate Change (UNFCCC), with strong inputs by the World Meteorological Organization (WMO), the UN Food and Agriculture Organization (FAO), and the Group on Earth Observations (GEO). The ECVs are documented in the Implementation Plan of the Global Climate Observation System (GCOS).
ICOS is a new research infrastructure under development at European level. It was identified in the ESFRI roadmap 2006 and is advancing since then. It is currently finalizing its implementation phase and becomes stepwise operational with the first data of labelled stations becoming available. *This initial phase is, however, the most delicate and difficult one for new pan-European infrastructures in the process to become fully operational as financial sustainability must be proved and the trust and awareness of users must be earned*, as the call INFRADEV-03-2016-2017 describes. The H2020 project "Readiness of ICOS for Necessities of integrated Global Observations" (RINGO) has come in time for ICOS, which has achieved the ERIC status in November 2015 and the Landmark status at the ESFRI Roadmap 2016. (For further information on the current status of ICOS see: ICOS ERIC Progress Report 2015 – 2017, published in August 2018).

ICOS is currently revising its strategy and preparing a 5-year action plan (for 2020 – 2024). RINGO enables these processes by unlocking resources for fulfilling these objectives:

1. *Scientific readiness*. To support the further consolidation of the observational networks and enhance their quality. This objective is mainly science-guided and will increase the readiness of ICOS RI to be the European pillar in a global observation system on greenhouse gases. The fulfilment of this objective is measurable by the activities performed in WP1:
    - Improving and supplementing the current observation networks of ICOS by improving sampling and measurement strategies (WP1, T1.2 – 1.4)
    - Bridging current ground-based ICOS observations to satellite data (WP1, T1.5)
2. *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. The fulfilment of this objective is measurable by the activities performed in WP2:
    - Strategy for enlarging the ICOS membership to increase the geographical coverage of the ICOS observations (WP2, T2.2)
    - Training potential ICOS members to be fully in line with ICOS technical and scientific standards (WP2 T2.3)

3. *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. The fulfilment of this objective is measurable by the activities performed in WPs 1 and 3:
    - Exploring the technological necessities to implement the scientific concepts developed in WP1
    - Developing and improving technical innovations within ICOS (WP3)
4. *Data readiness.* To improve data streams towards different user groups, adapting to the developing and dynamic (web) standards. The fulfilment of this objective is measurable by the activities performed in WPs 4 and 5:
    - Increasing the cross-domain interoperability of ICOS data through a meta-data type registry (WP4, T4.1);
    - Improving and making legacy (pre-ICOS) data available at the best possible quality including uncertainty information (WP4, T4.2)
    - Developing ICOS as a European pillar of domain-specific global networks to improve data interoperability (WP5, T5.2)
5. *Political and administrative readiness*. To deepen the global cooperation of observational infrastructures and with that the common societal impact. The fulfilment of this objective is measurable by the activities performed in WPs 1, 2 and 5:
    - Developing an impact assessment system for the current situation and future evaluations of the societal relevance of ICOS (WP1, T1.1)
    - Fostering capacity building in RI management and strengthening the national scientific communities of potential ICOS member countries (WP2, T2.1)
    - Building stable cooperation with other regional observational networks (WP5, T5.1)

With these objectives, RINGO will have a high impact on the future success of ICOS.

During the first 18 months (January 2017 – June 2018) which are reported here, the project has been thoroughly ramped up and first results have provided. The perhaps most important result is the impact analysis that has been performed during the first half of 2018. The final version has been released end of August 2018 right in time to be presented at the International Conference on Research Infrastructures at Vienna in September 2018.

ICOS is a distributed environmental research infrastructure and as such is facing specific challenges regarding its impact. The literature review performed by the GSF's Expert Group on RIs showed that there is still no answer to the question of how evaluation/assessment models established mainly for single-sited RIs could be extended to internationally distributed RIs, or how the size of an RI affects its impact. This is particularly relevant to the distributed or virtual RIs. It is clear however that, given the diversity of RIs, their impact on science, economy and society in different geographies is extremely variable. Impact assessment will differ with scale (e.g. national mid-scale vs. large international facilities), type (e.g. different pathways and productive interactions for single-sited vs. distributed vs. virtual e-RI) or discipline (e.g. applied technical science vs. social sciences and humanities vs. environmental observation platforms) (Moulin, 2016). The ICOS impact analysis performed within the RINGO project will, therefore, be influential beyond ICOS itself since it is the first document reflecting the mentioned challenges of distributed environmental RIs. In parallel, RINGO enables ICOS to review the observational networks technically as well as scientifically in order to better meet the requirements of a European GHG Verification system which once fully established will have a huge societal impact on the fulfillment of the Paris Agreement.

Increasing the ICOS membership and building capacities in so-called 'candidate countries' to join ICOS ERIC is crucial for the sustainability of the research infrastructure. RINGO has attracted nine national consortia

from candidate countries and will support them as well as it provides very useful resources to ICOS for establishing a process to attract new countries.

The work on technical innovation has been fully ramped up and the first results are very promising. There has been a RINGO-related campaign for air-core measurements at the Finnish ICOS site Sodankylä that also attracted external groups from the US. The instrumentation for atmospheric measurements on ships has been compiled an in one case tested on board of a vessel and will start the routine measurements during the second phase. Unmanned vehicles with ICOS Ocean instrumentation have been further developed. The ecosystem community has pushed forward the standardization of methane and N_2O flux measurements and a concept to prepare access to ICOS sites for co-location with other research infrastructures.

ICOS wants to improve its impact by implementing the FAIR principles for its entire data life cycle. The main work for that will be conducted in close cooperation with other research infrastructures in the ENVRIplus and the recently accepted ENVRIfair proposals. Notwithstanding, an important sub-process is conducted within the RINGO framework since it is targeting beyond the European research infrastructures to an operational global GHG information system: the standardized cataloging of metadata will ease the access to ICOS data and improve their usage. The re-processing and re-analysis of pre-ICOS data will also increase the value of the actual ICOS data since they can be interpreted in a historical context.

All mentioned activities will support the position of ICOS in the global GHG observation system. ICOS is becoming a blueprint for a regional research infrastructure and has used RINGO to further improve its connection to global data initiatives such as Global Atmosphere Watch (GAW), FLUXNET, SOCAt and GLODAP. Furthermore, the RINGO project is successfully supporting the liaison with UNFCCC, WMO and GEO.
Finally, it has to be mentioned that RINGO has a high impact on the internal integration of ICOS. The inclusion of the host institutions of the ICOS National Networks and Central Facilities has improved the internal cooperation and supported the cooperative spirit within the research infrastructure. The project also fostered the capabilities of ICOS ERIC to coordinate the distributed research infrastructure.

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

The project has fully completed 23 and partly completed 5 of the 28 milestones and 12 of the 13 Deliverables due in the first reporting period and hence is on track with its progress. Some re-adjustments to timelines were applied in order to maintain good standards of the work or to facilitate a more cost-effective way to organise activities (for detailed descriptions, see the table below and section 6). The following section describes work carried out by each beneficiary and the overall progress of the project during the first 18 months (January 2017- June 2018).

List of Deliverables delivered in this reporting period

WP1					
Deliverable Number	Deliverable Title	Lead beneficiary	Type	Dissemination level	Due Date (in months)

D1.1	Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs.	1 - ICOS ERIC	Report	Public	18 This deliverable is postponed to M25. See Section 6 'Deviations from DoA' for more details.
WP2					
D2.2	Concept document on collaboration with countries and stations outside European Union	1 - ICOS ERIC	Report	Public	12
D2.4	Online platform as part of ICOS webpages including technical and scientific training material.	6 - UVGZ	Websites, patents filling, etc.	Public	12
WP3					
	No deliverables due in WP3 in this reporting period				
WP4					
	No deliverables due in WP4 in this reporting period				
WP5					
D5.1	Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO.	1 - ICOS ERIC	Report	Public	16
WP6					
D6.1	Organisation of project Kick-off meeting, including an Executive Board and a General Assembly meeting.	1 - ICOS ERIC	Other	Public	3
D6.2	Project website and internal communication (intranet, email-lists, telephone connections) operational.	1 - ICOS ERIC	Demonstrator	Public	6
D6.3	Project Dissemination Strategy	1 - ICOS ERIC	Report	Public	6
D6.4	Initial Data Management Plan (DMP).	1 - ICOS ERIC	Report	Public	6
D6.5	Initial Risk Management Plan.	1 - ICOS ERIC	Report	Public	6
D6.6	First Updated Project Dissemination	1 - ICOS ERIC	Report	Public	18
D6.7	First Updated Data Management Plan	1 - ICOS ERIC	Report	Public	18

D6.8	First Updated Risk Management Plan	1 - ICOS ERIC	Report	Public	18
D6.9	Periodic Report 1 including request for first interim payment	1 - ICOS ERIC	Report	Public	18

List of Milestones achieved during this reporting period

WP1				
Milestone number	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS6	First draft of strategy document on increasing impact of ICOS provided for internal discussions	1 - ICOS ERIC	12	First draft of strategy document on increasing impact of ICOS provided for internal discussions
MS7	Site selection, description and footprint estimate for fossil fuel detection pilots provided	5 - UHEI	12	Site selection, description and footprint estimate for fossil fuel detection pilots provided
MS8	TCCON and ICOS data integration workshop held	24 - UBremen	12	TCCON and ICOS data integration workshop held
MS15	Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs.	1 - ICOS ERIC	18	Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs. This Milestone is delayed and will be finalised by 31.1.2019
MS16	Prototype systems for selected integrated and grab sampling of $ffCO_2$ emissions available	5 - UHEI	18	Prototype systems for selected integrated and grab sampling of $ffCO_2$ emissions available In progress; but not finalised. Detailed description in the narrative part.
MS17	Available data on long- term records of continuous greenhouse gas mole fractions and co-located flask samples compiled	5 - UHEI	18	Available data on long- term records of continuous greenhouse gas mole fractions and co-located flask samples compiled
MS18	Pilot retrieval of the satellite data for surface temperature (SST), skin effects, wave state and wind speeds developed	8 - NERC	18	Pilot retrieval of the satellite data for surface temperature (SST), skin effects, wave state and wind speeds developed
MS19	Skogaryd Research Catchment workshop held	10 - ULUND	18	Skogaryd Research Catchment workshop held

MS20	TCCON and ICOS technical integration workshop held	4 - UVSQ	18	TCCON and ICOS technical integration workshop held This workshop will be organised in September 2018 alongside the ICOS Science Conference, as it is more cost-effective and convenient as most participants are there anyway.
WP2				
MS9	Concept document on collaboration with countries and stations outside European Union	6 - UVGZ	12	Concept document on collaboration with countries and stations outside European Union
MS10	Virtual training platform available for upload of e-learning material	6 - UVGZ	12	Virtual training platform available for upload of e-learning material
MS11	Initial workshop on manager training for new countries held	6 - UVGZ	12	Initial workshop on manager training for new countries held
MS21	First draft of report on enhancing membership strategy for ICOS ERIC to be discussed in ICOS ERIC bodies	6 - UVGZ	18	First draft of report on enhancing membership strategy for ICOS ERIC to be discussed in ICOS ERIC bodies
WP3				
MS12	High accuracy in situ vertical profile measurements started	7 - RUG	12	High accuracy in situ vertical profile measurements started
MS22	CO_2 instrument build and incorporated into an ASV to make an ASV-CO_2 vehicle	23 - GEOMAR	18	CO_2 instrument build and incorporated into an ASV to make an ASV-CO_2 vehicle MS is not yet completed, we expect a delay of order 4 months, The CO2 instrument build is well underway but the integration into a vehicle is not complete, since we have had problems accessing a vehicle. We have risk mitigation strategies in place and we will achieve our goals I am confident, but we have not done so yet.
MS23	Common data set for non-CO_2 eddy covariance measurements compiled from existing sites	9 - UHEL	18	Common data set for non-CO_2 eddy covariance measurements compiled from existing sites In progress - work has been going on and progress has

				been made (detailed description in the narrative part)
WP4				
MS17	Available data on long- term records of continuous greenhouse gas mole fractions and co-located flask samples compiled	5 - UHEI	18	Available data on long- term records of continuous greenhouse gas mole fractions and co-located flask samples compiled
WP5				
MS13	Memorandum of Understanding for global cooperation drafted and start of negotiations with comparative regional networks	1 - ICOS ERIC	12	Memorandum of Understanding for global cooperation drafted and start of negotiations with comparative regional networks
MS14	Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO	1 - ICOS ERIC	16	Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO
MS24	Basic GLODAP and SOCAT services implemented at OTC	2 - UiB	18	Basic GLODAP and SOCAT services implemented at OTC
WP6				
MS1	Kick-off organized, including an Executive Board and a General Assembly meeting	1 - ICOS ERIC	3	Kick-off organized, including an Executive Board and a General Assembly meeting
MS2	Establishment of RINGO webpages as part of the ICOS website and internal communication	1 - ICOS ERIC	6	Establishment of RINGO webpages as part of the ICOS website and internal communication
MS3	Dissemination strategy	1 - ICOS ERIC	6	Dissemination strategy
MS4	Initial Data Management Plan	1 - ICOS ERIC	6	Initial Data Management Plan
MS5	Risk management plan	1 - ICOS ERIC	6	Risk management plan
MS25	First Updated Project Dissemination	1 - ICOS ERIC	18	First Updated Project Dissemination
MS26	First Updated Data Management Plan	1 - ICOS ERIC	18	First Updated Data Management Plan
MS27	First Updated Risk Management Plan	1 - ICOS ERIC	18	First Updated Risk Management Plan
MS28	Periodic Report 1 including request for first interim payment	1 - ICOS ERIC	18	Periodic Report 1 including request for first interim payment

3. Objectives

While the implementation of ICOS is well underway and supported by the national resources provided by the member and observer countries, the challenge for sustainability of ICOS is defined by its readiness to further develop in the described direction. The societal requirements as well as the scientific and technical

developments in the field of greenhouse gas research are so dynamic that ICOS needs support for permanent innovation. The proposed project “Readiness of ICOS for Necessities of integrated Global Observations” (RINGO) will define these challenges and further develop the readiness of ICOS RI to meet them. It will have five principal objectives:

6. *Scientific readiness*. To support the further consolidation of the observational networks and enhance their quality. This objective is mainly science-guided and will increase the readiness of ICOS RI to be the European pillar in a global observation system on greenhouse gases. The fulfilment of this objective is measurable by the activities performed in WP1:
    - Improving and supplementing the current observation networks of ICOS by improving sampling and measurement strategies (WP1, T1.2 – 1.4)
    - Bridging current ground-based ICOS observations to satellite data (WP1, T1.5)
7. *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. The fulfilment of this objective is measurable by the activities performed in WP2:
    - Strategy for enlarging the ICOS membership to increase the geographical coverage of the ICOS observations (WP2, T2.2)
    - Training potential ICOS members to be fully in line with ICOS technical and scientific standards (WP2 T2.3)
8. *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. The fulfilment of this objective is measurable by the activities performed in WPs 1 and 3:
    - Exploring the technological necessities to implement the scientific concepts developed in WP1
    - Developing and improving technical innovations within ICOS (WP3)
9. *Data readiness.* To improve data streams towards different user groups, adapting to the developing and dynamic (web) standards. The fulfilment of this objective is measurable by the activities performed in WPs 4 and 5:
    - Increasing the cross-domain interoperability of ICOS data through a meta-data type registry (WP4, T4.1);
    - Improving and making legacy (pre-ICOS) data available at the best possible quality including uncertainty information (WP4, T4.2)
    - Developing ICOS as a European pillar of domain-specific global networks to improve data interoperability (WP5, T5.2)
10. *Political and administrative readiness*. To deepen the global cooperation of observational infrastructures and with that the common societal impact. The fulfilment of this objective is measurable by the activities performed in WPs 1, 2 and 5:
    - Developing an impact assessment system for the current situation and future evaluations of the societal relevance of ICOS (WP1, T1.1)
    - Fostering capacity building in RI management and strengthening the national scientific communities of potential ICOS member countries (WP2, T2.1)
    - Building stable cooperation with other regional observational networks (WP5, T5.1)

4. Explanation of the work carried out per Work Package

Work Package 1: Increasing the impact of ICOS

Lead Beneficiary: (5) UHEI

The main objective of WP1 is to improve the impact and scientific readiness of ICOS for meeting future challenges in European and global GHGs budgeting, including top-down verification of COP21 commitments. The work package is organised in five tasks concerned with tackling scientific as well as socio-economic aspects:

- 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 CO_2 and verification of its emission inventories, (ii) supplementary and stable isotope tracers analysed on flask samples for CO_2 and CH_4 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.

The work carried out in WP1 during the first periodic reporting period (M1-M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

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: 1- ICOS ERIC
Beneficiaries involved in T1.1: 1 – ICOS ERIC

The overall goal of the task is to provide an in-depth analysis of the impact of ICOS as part of an updated strategy for the further development of ICOS that has become operational and an ESFRI Landmark. The call for tenders according to EU and ICOS ERIC procurement rules has been prepared during the first months of the project.

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

D1.1: Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs (M18)
This deliverable is postponed to M25 due to retarded sub-contraction of the impact analysis. The timeline for the thorough execution of the analysis was re-scheduled and the deliverable will be finalized by 31.1.2019.
List of Milestones due to be completed within this reporting period:

Milestone	Milestone title	WP number	Lead Beneficiary	Due Date (in months)	Means of verification
MS6	First draft of strategy document on increasing impact of ICOS provided for internal discussions.	1	1 ICOS ERIC	M12 – postponed to M16	First draft of strategy document on increasing impact of ICOS provided for internal discussions
MS15	Strategy document on increasing impact of ICOS including a recommendation	1	1 ICOS ERIC	M18 – postponed to M25	Strategy document on increasing impact of ICOS including a recommendation to ESFRI for

	to ESFRI for recommendation to ESFRI for comprehensive impact analyses for environmental RIs.			This milestone, corresponding to D1.1, is postponed to M25 due to retarded sub-contraction of the impact analysis. The timeline for the thorough execution of the analysis was re-scheduled and the milestone will be finalized by 31.1.2019	comprehensive impact analyses for environmental RIs.

Description of work carried out in T1.1 by beneficiary 1 – ICOS ERIC
Beneficiary (1) ICOS ERIC contributed to Milestones MS6 and MS15 by defining and running the procurement of the sub-contract and provided guidance, necessary data (bibliometrics, users, financial data etc.) and feedback during the analysis. The overall resources used for this were 2.12 PM. The impact analysis is being conducted by Technopolis.

Results achieved so far:

The impact analysis run by Technopolis was kicked off in January 2018 and the draft report came to the following conclusions:

"This is the first impact assessment of a distributed environmental research infrastructure. The methodology we used, and pitfalls that we encountered, can inform future impact evaluations of this type. Although there are many variables that affect impact, such as size, level of distribution and field of research, we found that the high level of internal organisation in ICOS was a key factor in its ability to reach its aims.

Although in many cases it is too early to review quantitative evidence of the impact that ICOS has generated, this study has gathered a substantial base of qualitative evidence for ICOS' impacts. Together with the available documentation and survey results, it paints a picture of a research infrastructure that is highly relevant within the European GHG research community. It has obtained this position for an important part through the successful implementation of measurement protocols throughout the research infrastructure, and its ability to provide datasets of consistently high quality.
One of the core tasks of ICOS since the start has been, and still is, the development of the standardization requirements of the National Networks. Although many stations are still awaiting approval, the first stations that have undergone the station labelling process have now received the status of an official ICOS station, and are publishing data through the Carbon Portal (CP).

Despite the long duration of this process, and the fact that data are only now becoming available, scientists working with ICOS are very positive about the improvements in data quality that ICOS has brought about: not only the quality of the physical measurements done by the measurement stations, but also to the transparency of the data processing chain, and reliability of the data quality. According to scientists themselves, improvements in data quality and the harmonising of data processing protocols across measurement stations are already improving the quality of scientific output. With the projection that by the

end of 2019, 80–90 % of the stations will be labelled, the focus of the thematic centres is expected to shift more and more towards the further development of the ICOS RI, through data analysis and providing support to the national networks. In many cases this is a desired development for the scientists involved.

Despite the clear narrative on ICOS scientific impact, it was not possible to measure this using traditional methods like bibliometrics of academic publications. This is a direct consequence of the fact that official ICOS data have only very recently become available, and that the impact of academic publications occurs with a time lag. The bibliometric analysis that was performed using publications which predate the ICOS ERIC indicate the high potential that regularly updated ICOS data from ICOS certified stations has, both inside and outside the academic world. The fact that there is a high uptake of ICOS' data-related services and global data products, even in the absence of ICOS-certified measurements, suggest that ICOS fulfils a need in providing a platform for data analysis. The DOI minting process recently implemented by ICOS should improve attribution to ICOS in academic publications and can potentially be used to improve attribution to ICOS data products, provided that this process is adequately implemented.

ICOS effectiveness to unify the European climate science field has also had effects on innovation and R&D. These originate mostly from the fact that ICOS is a single large procurer with high demands. Suppliers of sensors and other measurement instrumentation mention that being an ICOS client counts as a sort of quality certificate. Upstream economic impacts in the way of investments mobilized by ICOS are significant and are primarily related to country contributions, 90% of which is used for national network development and further development of central facilities.

ICOS is firmly integrated in the European research infrastructure landscape, certified by the large number of joint research activities with other RIs, and the use of various methods and practices developed by ICOS in other research infrastructures. At the same time ICOS is involved in a wide range of projects with a global coverage. The large number of services and collaborations linked to global projects is testimony of the fact that the data gathered by ICOS have added value to the research community beyond the ICOS members.

The combination of reliable high-quality data on GHG, pan-European coverage and the presence of a research community means that ICOS data, even in their early stage, are already used by various communities and organizations who provide information to policy-makers. The 'contribution of timely information relevant to the GHG policy and decision-making' is one of ICOS' explicit aims, and at the same time an example of an outcome where it is very difficult, if not impossible, to attribute impact to ICOS. The narrative is that knowledge about what type of information is required to reach decision-makers, about where ICOS data can contribute to improve policy decisions, and about what the current visibility of ICOS is, is crucial help to monitor ICOS' relevance to climate action support. One example of this is the Fifth Assessment Reports (AR5) of the IPCC, where ICOS contributed to several datasets.

In addition, the AR5 report makes the explicit recommendation to use longer time-series in the estimation of changes in atmospheric concentrations of GHG. ICOS can deliver these data, and thus this can be read as a clear mandate for ICOS to produce this type of data."

The ICOS-internal process will be concluded by the end of the year 2018. The Deliverable D 1.1 "*Strategy document on increasing impact of ICOS including a recommendation to ESFRI for comprehensive impact analyses for environmental RIs*" will be provided by 31.1.2019.

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

MS6:

Internal communication has been slower than expected, subsequently resulting in the need to extend the internal round for comments so that the milestone was achieved in M16.

MS15 and D1.1:
The procurement process for sub-contracting the impact analysis was launched in July 2018 (Month 7) but had to be re-launched in September (Month 9) to fully comply with the Finnish national regulations for procurements. This caused some delay in Milestones MS6 and MS15 related to this task. The timeline for the thorough execution of the analysis was re-scheduled and the milestone will be finalized by 31.1.2019

The consequences of the delay are not critical. In fact, it fits even better in the time line of the further development of ICOS since the impact analysis will serve as one element of the updated strategy and is now in phase with other ICOS internal processes to update the strategy (internal consultation with different bodies, external communication with users and stakeholders).

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

Task leader: (5) UHEI
Beneficiaries involved in T1.2: (10) ULUND, (4) UVSQ, (7) RUG, (7) RUGWU

The current atmospheric ICOS class 1 station network is set up to monitor natural carbon fluxes and thus stations were originally selected to have minor influence from fossil fuel CO_2 ($ffCO_2$) sources. The aim of Task 1.2 is to increase the ICOS readiness to monitor $ffCO_2$ emissions from emission hot spots by designing and testing new sampling strategies in both the reality and the model world.
The main achievements in the reporting period were that new stations for the two-station approach have been selected in the three metropolitan/industrial areas in Germany, France and The Netherlands on the basis of preliminary model simulations for the respective areas. These stations are currently in the process of being instrumented. In addition, planning of an Observation System Simulation Experiment (OSSE) to optimise future monitoring of $ffCO_2$ in Europe was started.

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
MS7	Site selection, description and footprint estimate for fossil fuel detection pilots provided	WP1	5 UHEI	12	Site selection, description and footprint estimate for fossil fuel detection pilots provided

Description of work carried out in T1.2 by beneficiary 5-UHEI

Beneficiary (5) UHEI contributed to Milestone MS7:
For the Rhine Valley a station pair (up- and downwind of a hot spot region) had to be selected. Therefore, UHEI evaluated different STILT model simulations of atmospheric CO_2 concentrations in the Rhine Valley, which were provided by the ICOS Carbon Portal. For the existing stations Karlsruhe (KIT) and Heidelberg (HEI) potential background stations were tested and evaluated. In addition, a station pair in the Ruhr area using Jülich (JUE) as upwind side was considered. For each station pair in the Rhine Valley different sampling strategies, either based on local wind conditions or modelled trajectories, were tested. The trajectory-based

sampling events were also calculated and provided for the Paris and the Rotterdam station pairs. Based on the modelled $ffCO_2$ gradients between the station pair and the feasibility of operating the station pair, we chose Heidelberg as downwind site with an upwind site west of the metropolitan area of Mannheim/Ludwigshafen. From the model simulations we expect a median $ffCO_2$ signal on the order of 3–4ppm, which originates to about 2/3 from the hot spot area. The actual location of the upwind station was selected to be at the freshwater reservoir of Freinsheim. The municipal administration agreed to host the new station.

In parallel to the evaluation of the model simulations, a prototype of an integrating flask sampler was tested in Heidelberg. The sampler is capable of sampling ambient air in 3L flasks over 1 to 6 hours. The sampling can also be ceased during the sampling of one flask. The average difference between continuous measurements (either FTIR or Picarro) minus the flask measurement are -0.26 ± 0.29 ppm for CO_2 and -1.8 ± 7.0 ppb for CO for the FTIR comparison or -0.04 ± 0.05 ppm for CO_2 and 0.14 ± 2.39 ppb for CO for the Picarro comparison, respectively. Based on lessons learned from the prototype, the production of the Freinsheim sampler and the two samplers for Paris is currently ongoing. We expect to deploy the Freinsheim sampler in September 2018.

To investigate the benefit in quantifying $ffCO_2$ emissions using the two-station approach in a potential European ICOS 2.0 network, we plan to conduct an Observation System Simulation Experiment (OSSE). The OSSE experiment will be conducted by the partners RUG_WU and UVSQ and evaluate two different sampling networks and strategies. UHEI contributed to the design of the OSSE.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the implementation plan

Deviations from the planned use of resources

Deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T1.2 (and T1.3, see below) was not available. The evaluation of existing data and modelling results was therefore done by Fabian Maier (Master student) and Samuel Hammer (ICOS-CRL) using in-kind resources. The PMs of UHEI for T1.2 (8 PM scientist) will be transferred to 12 PM engineer (J. Della Coletta), who will take care of the sampling site in Freinsheim and will measure and evaluate the $^{14}CO_2$ analyses on the flasks collected in Freinsheim.

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.2 by beneficiary 10-ULUND

Beneficiary (10) ULUND contributed to Milestone MS7:

ICOS Carbon Portal at Lund University provided STILT model simulations of atmospheric CO_2 concentration and sensitivity footprints for potential station pairs to evaluate the expected fossil fuel CO_2 signals and support the station selection. Model simulations were carried out for the existing stations Heidelberg and Karlsruhe, as well as for five potential sites in the Rhine valley and the Ruhr region. The simulations were based on a high-resolution fossil fuel emission inventory (EDGAR v4.3) extended by information on monthly, weekly and daily time profiles for the emission sectors. The emissions from different fuel types and specific emission

sectors were transported separately to allow for an evaluation of their respective shares in the concentration signal. Additional simulations for several emission scenarios were conducted to help identifying the contributions from specific regions on the potential concentration signals at the station pairs. Simulated wind and planetary boundary layer height were provided to evaluate additional selection criteria.
ICOS Carbon Portal also provided a virtual research environment based on Jupyter notebooks for the collaborative evaluation of model simulations in preparation of the station selection.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
No unforeseen subcontracting
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
No unforeseen contribution from third party

Description of work carried out in T1.2 by beneficiary 4-UVSQ

The two monitoring stations selected for the RINGO project are located in the axis of the prevailing winds of Paris (Figure 1). In the south-west direction the tall tower of Saclay (sampling levels at 15, 60 and 100m above ground-level) is fully equipped with continuous measurements of greenhouse gases (Figure 2) and meteorological parameters, and an ICOS integrated ^{14}C sampler since June. At the opposite direction of Paris two stations can be used for the installation of the flask sampler: Gonnesse or Coubron. Both sites are equipped with in situ analyzers of CO_2/CH_4/CO (Figure 2). A meteorological station has been purchased and will be installed at the station which will be equipped with the sampler. At the Gonnesse station we observe CH_4 spikes probably due to a waste centre located few kilometres north. However, no such spikes are observed for CO_2 or CO.

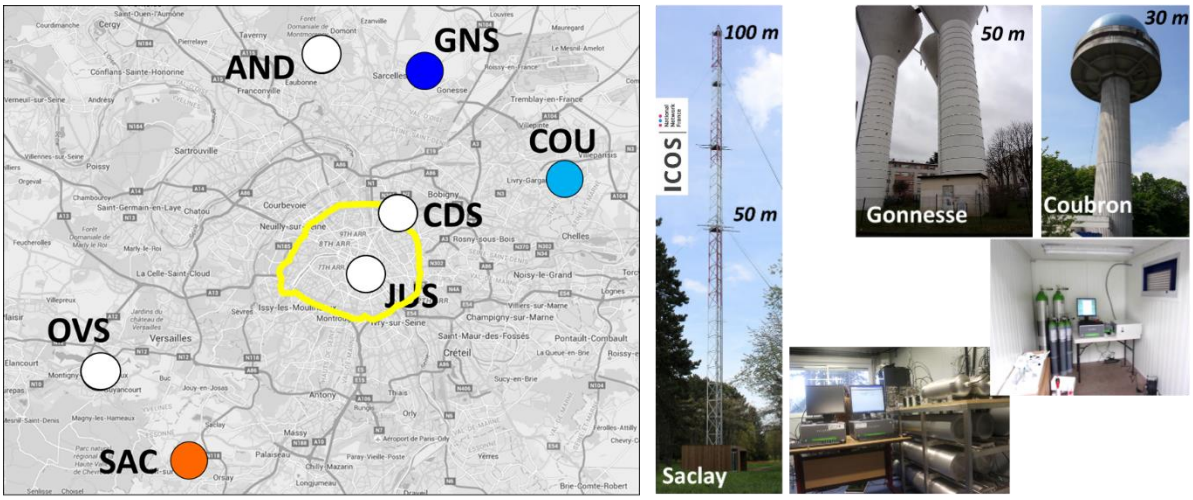

Figure 1: Left: map of the monitoring stations around Paris. Right: pictures of the sites and analyzers.

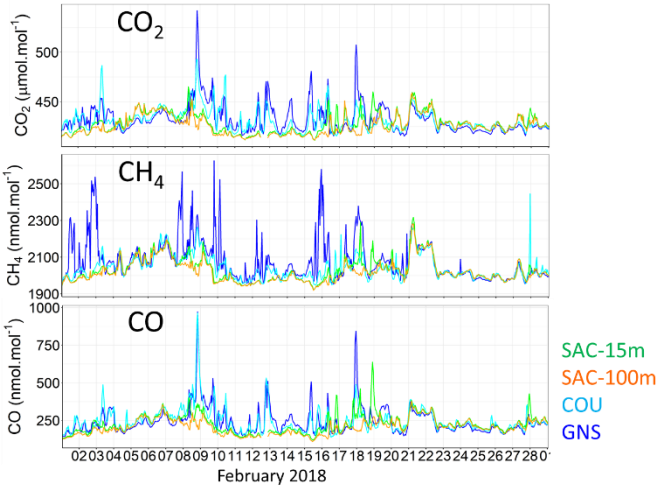

Figure 2: Time series of CO2, CH4 and CO at Saclay, Gonnesse and Coubron stations in February 2018.

The atmospheric transport model CHIMERE has been used to simulate CO_2 concentrations around Paris with a horizontal resolution of 0.5°x0.5°, and with IER-Carbons and ODIAC inventories for the anthropogenic emissions, and Orchide model for the biospheric fluxes. The comparison of the Saclay and Gonnesse observations with the CHIMERE simulations (Figure 3) show too high concentrations at GNS. This is due to the model resolution, which locate GNS in a grid cell containing Paris emissions. A better agreement is found when selecting one grid cell further north. The ODIAC inventory also provides better comparison with observations, compared to IER-Carbons. UVSQ contributed to the design of the OSSE with UHEI and RUG.

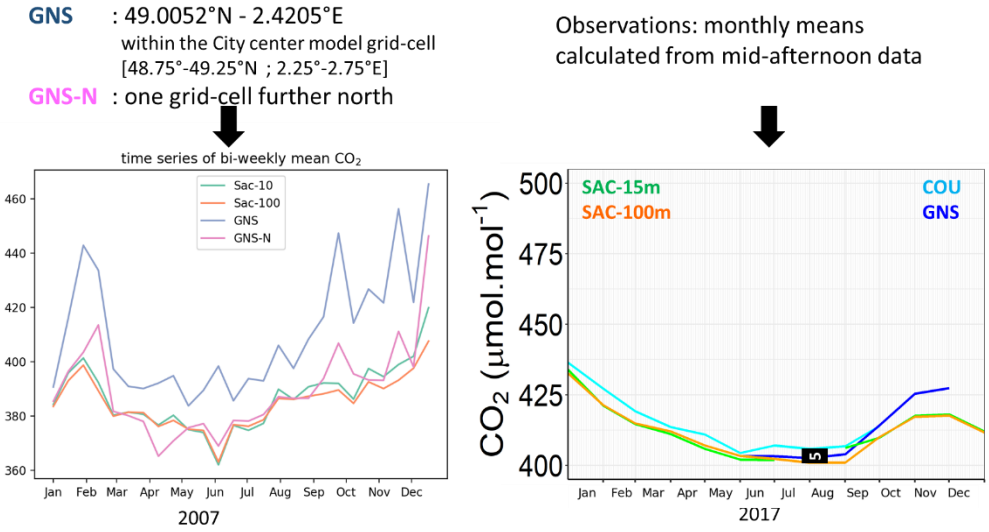

Figure 3: Mid-afternoon CO2 concentrations at Gonnesse and Saclay simulated by the CHIMERE model (left) and observed (right).

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

No deviations from DoA

Deviations from the implementation of task

No deviations from DoA

Deviations from the planned use of resources

No deviations from DoA

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.2 by beneficiary 7-RUG

Beneficiary (7) RUG contributed to Milestone MS7:

Site selection results

In October 2017, a visit was made to the Rotterdam area to investigate the possible locations for the new atmospheric stations. Various places in the 2nd Maasvlakte harbour and the Rockanje village (Figure 4) were examined.

Figure 4: Site visit in October 2017. The red dots are the locations visited, amongst which four were chosen for further assessment

Of all the places (marked by the red dots on Figure 4), four particular locations were considered further due to their favourable features fitting the selection criteria:

- proximity to the coast,
- availability of utilities (internet, electricity, lighting) and personnel, and
- accessibility and security.

Out of the above four, the port authority (PA) building was the most outstanding location, due to having 24/7 double-layer security guards; all-year access to the building; and readily available electricity, lighting, and internet within an air-conditioned, secured room. Despite being a little further in-land than its counterparts, the advantages of the PA building are more valuable than the other locations. As of December 2017, the PA location was authorised for use by the managers of the building.

Monitoring strategy

In order to get a general idea of the atmospheric composition at the site in response to the industrial/shipping activities and various wind characteristics, a Picarro has been prepared and brought from the University of Groningen to the site. There, the Picarro is set up in a secured room, along with a computer monitor to observe the analysed output, a vacuum pump from Picarro Inc. to transfer the air sample from the inlet to the inside of the machine, a 3G router to connect the system to the internet (to transfer data files from the machine to an online data server, and for remote monitoring), and other peripheral equipment.

To get the air from outside to the Picarro, 25m of ¼" Synflex tubing was used to connect the Picarro on one end to a filtering funnel on the other (Figure 5). The funnel contains two layers of filters – a (outer) mesh fibre

filter to remove dirt, insects, and other coarse contaminants, and a (inner) 2-micron Teflon filter to remove extremely fine contaminants from the air stream.

Figure 5: The filtering funnel on the air inlet

After the ^{14}C sampling system will be finished and deployed at the Rotterdam site, the Picarro will still be used to take continuous atmospheric measurements of the site along with the ^{14}C sampling process. Then, also at least one cylinder (preferably two, or even three) with reference air will be installed for a periodic check of the calibration of the Picarro. Preferably, a weather station will also be installed at the site to give exact meteorological measurements along with the other equipment, however this needs to be discussed with the manager of the building.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions
No deviations from DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.2 by Linked Third Party 7-RUG_WU

Linked Third Party (7) RUG_WU contributed to Milestone MS7:
RUG_WU performed forward atmospheric model runs to analyse which locations in the Rotterdam-Rijnmond area could be suitable to serve as atmospheric station pairs to monitor the CO_2 and CO concentrations gradients related to the CO_2 and CO emissions in the area. We found that a location on the 2nd Maasvlakte (an artificial forefront port area into the North Sea) is suitable as upwind station, because the concentrations in a wide range of wind directions from the North Sea are undisturbed (Figure 6). The existing station Cabauw is a suitable downwind station, as it may detect the CO_2 and CO signals from the emissions in the metropole

and sea port/industrial area, obviously depending on the wind directions (Figure 6). This information was shared with partner RUG, who proceeded with installing the necessary equipment at the two locations.

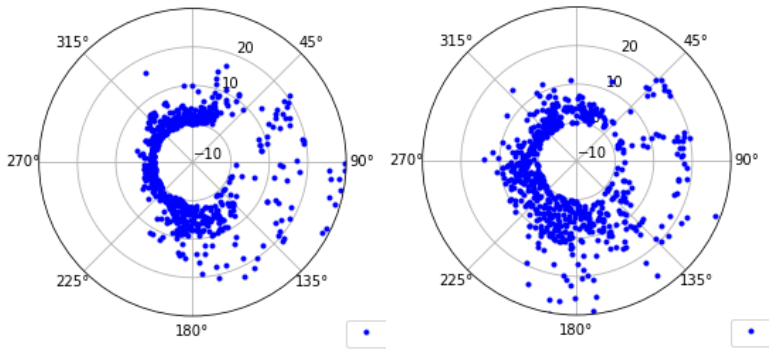

Figure 6: Windroses of the fossil fuel CO_2 concentration in ppm in 2nd Maasvlakte (left) and Cabauw (right).

The sea exposed 2nd Maasvlakte location shows undisturbed fossil fuel CO_2 signals for wind directions between 200° and 20°, and the Cabauw station clearly shows the increments in fossil fuel CO_2 concentrations in the direction of Rotterdam-Rijnmond (~270°).
Next, we analysed under which meteorological conditions the fossil fuel CO_2 and CO gradients between the two stations correlate best with the emissions (Figure 7). This analysis shows that strict selection of the conditions is necessary to obtain an acceptable correlation. Conditions include wind speed larger than 4 ms^{-1}, wind direction change in time and between stations smaller than 15°, $ffCO_2$ signal larger than 3 ppm, afternoons, and boundary layer height larger than 200 m and not changing more than 500 m in 2 hours. These selection criteria may help to interpret the CO_2 and CO observations at the upwind and downwind stations, which will be done by partner RUG.

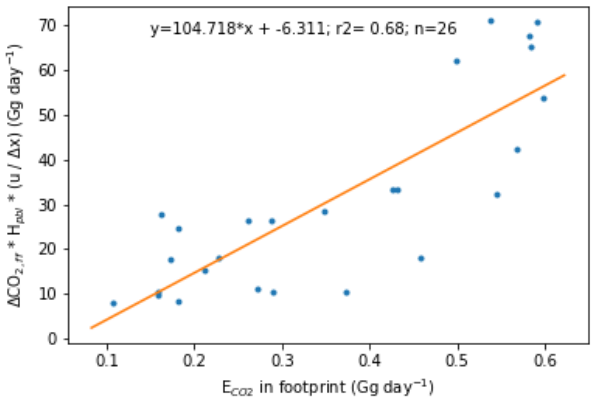

Figure 7: Correlation between CO_2 emissions in the footprint of the Cabauw station and the fossil fuel CO_2 gradient between the upwind and downwind stations.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Task 1.3: Developing the ICOS Flask sampling strategy

Task leader: (5) UHEI
Beneficiaries involved in T1.3: (1) ICOS ERIC

Flask sampling at ICOS (class 1) stations has two aims: (1) Comparison of flask and continuous measurements shall provide an independent means for quality control of ICOS atmosphere data, and (2) analysis of components in the flasks, which are not measured in situ at the stations, such as $^{14}CO_2$, will provide information that can be used to disentangle GHGs sources and sinks in their footprint.
UHEI and ICOS ERIC Carbon Portal have evaluated continuous observations from ICOS stations together with model results to develop a preliminary strategy for effective flask sampling. This strategy was discussed at two ICOS atmospheric Monitoring Station Assemblies and it will also be discussed with the modelling community during the TRANSCOM modelling workshop in September 2018.

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
MS17	Available data on long-term records of continuous greenhouse gas mole fractions and co-located flask samples compiled	WP1	5 UHEI	18	Available data on long-term records of continuous greenhouse gas mole fractions and co-located flask samples compiled

Description of work carried out in T1.3 by beneficiary 5-UHEI

Beneficiary (5) UHEI contributed to Milestone MS17
UHEI, together with ICOS Carbon Portal, used in situ measurements and STILT modelling results from/for the ICOS stations OPE, Gartow and Karlsruhe to evaluate the variability of continuous CO_2 concentration data during afternoon hours as well as for investigating the strengths of fossil fuel CO_2 signals from individual emission hot spots in the catchment area of these stations. For aim (1), a preliminary sampling strategy was developed and discussed with ICOS station PIs during the atmosphere MSAs in November 2017 and in June 2018. It was decided to test the simplest strategy at the Heidelberg pilot station, where an ICOS flask sampler prototype is currently evaluated. We are now sampling at the pilot station one flask every day during the afternoon hours (i.e. between 13 and 17 local time), which is analysed at the FCL in Jena. The CO_2, CO and CH_4 results from the flask samples are then compared to the respective continuous measurements at the pilot station. Preliminary results of this comparison will be presented at the next atmosphere MSA in Prague in September 2018.

The CRL has also started ^{14}C analysis on these regularly collected flasks to evaluate their usefulness for fossil fuel CO_2 determination in the catchment area of Heidelberg (aim 2). Together with $^{14}CO_2$ analyses on flasks to be collected at a new sampling station in Freinsheim, which will be set up by the end of summer

2018 in the framework of Task 1.2 to monitor the Mannheim-Ludwigshafen metropolitan area with the so-called two-station approach, these results will feed into the development of a strategy for optimally monitoring fossil fuel CO_2 emissions in Europe.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the implementation plan

Deviations from the planned use of resources

Deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T1.3 (and T1.2, see above) was not available. The evaluation of existing data and modelling results was therefore done by the PI (I. Levin) using in-kind resources. The PMs of UHEI for T1.3 (6 PM scientist) will be transferred to 9 PM engineer (J. Della Coletta), who will take care of, measure and evaluate the $^{14}CO_2$ analyses on the flasks collected at the Heidelberg pilot station.

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.3 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC contributed to Milestone MS17:
ICOS Carbon Portal provided STILT model simulations of atmospheric CO_2 concentration and sensitivity footprints for the ICOS stations OPE, Gartow and Karlsruhe. In the model simulations, concentration signals from biospheric fluxes and fossil fuel emissions are transported separately to evaluate their respective shares in the total CO_2 concentration. The simulated footprints, or catchment areas of the stations, together with emission maps, depict the sensitivity of the resulting atmospheric CO_2 concentration to specific emission regions or hot spots in the catchment.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the implementation plan

Deviations from the planned use of resources

No deviations from planned use of resources

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

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

Task leader: (8) NERC
Beneficiaries involved in T1.4.: (3) UNITUS_CNR, (3) UNITUS_ENEA, (3) UNITUS_OGS, (9) UHEL, (9) UHEL_FMI, (10) ULUND, (10) LU_UGOT, (10) LU_MET, (10) LU_UUPP; ETHZ, (8) NERC_UoE, (8) NERC_PML, (12) Uant_VLIZ.

The overall goal of T1.4 is to develop methodologies of budgeting lateral carbon and GHGs fluxes via rivers, streams, estuaries and oceans. This should be achieved through 3 dedicated workshops. During the reporting period, the first workshop was conducted at Skogaryd (Sweden) from March 14 – 16, 2018 with the aim to ”Determine the current status of European land-ocean carbon fluxes and the associated monitoring methodologies (WS1)”.

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
MS19	Skogaryd Research Catchment workshop held	WP1	8 NERC	18	Skogaryd Research Catchment workshop held

Description of work carried out in T1.4 by beneficiary 8-NERC

Beneficiary (8) NERC contributed to Milestone MS19 by liaising with the workshop organisers (UGOT, LU), participating in workshop and chairing workshop sessions.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 3-UNITUS_CNR

Beneficiary (3) UNITUS_CNR contributed to Milestone MS19 by participating in the workshop held at the Skogaryd Research Catchment in Sweden (14-16th March, 2018), where the presentation entitled "Variabilities of sea surface pCO_2 in the Gulf of Trieste (PALOMA station) and estimates of air sea CO_2 winter fluxes" was given (see workshop summary).
According to what was discussed during the workshop, the on-line questionnaire designed to capture information on the measurement of land-ocean carbon fluxes throughout Europe was filled in and distributed to other contacts in Italy**.**

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan

Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 3-UNITUS_ENEA

Beneficiary 3 UNITUS_ENEA contributed to Milestone MS19 by participating to the annual meeting held in Belgium at the University of Antwerp, from Tuesday 20th March to Thursday 21nd March, 2018.
The Beneficiary contributed to the general discussion and to the Ocean Workshop dealing with integration of ecosystem measures and sea-air fluxes exchange in Lampedusa.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
No deviations from the DoA
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
No deviations from the DoA

Description of work carried out in T1.4 by beneficiary 3-UNITUS_OGS

Beneficiary (3) UNITUS_OGS contributed to Milestone MS19
Michele Giani (UNITUS_OGS) presented a communication entitled “Seasonal variability of CO_2 system in the coastal waters of the Trieste Gulf (Marine Protected Area of Miramare)” at the Workshop 1, titled ”Determine the current status of European land-ocean carbon fluxes and the associated monitoring methodologies” held in Skogaryd, Skogaryd/Örtgården (Sweden), from 14 to 16th March 2018. The presentation aimed to show the main features influencing the CO_2 variability and the air-sea exchanges in the coastal waters of a northern Mediterranean sea. Michele Giani participated to the field visit of various sites within the Skogaryd research catchment, observing the installation of eddy covariance flux towers and SkyGas systems in both terrestrial and lake environments. During the second day, Michele Giani participated to the demonstration of the low-cost, automated gas flux chambers, developed by David Bastviken and colleagues, and a further field visit to see a range of sensor installations in a forested catchment. He participated to the discussion focussed around the latest global estimates of land-ocean carbon fluxes and on the approach to integrate old and new data on carbon fluxes, determined using different methodologies. On the third day, Michele Giani contributed to the formulation of an on-line questionnaire ”The current status of European land-ocean carbon fluxes and future research priorities” on the availability of data about carbon monitoring in Europe.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA

Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 9-UHEL

Beneficiary (9) UHEL contributed to Milestone MS19 by participating to the Workshop and initiating a new ICOS Working Group aiming to the definition of standard methods for fluxes and meteorological measurements over water bodies such as lakes and sea.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 9-UHELFMI

Finnish Meteorological Institute 9-UHEL_FMI is a Linked Third Party to 9-UHEL and contributed to MS19 by participating in the Skogaryd Research Catchment workshop and review on available monitoring sites.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 10-LU

Beneficiary (10) LU contributed to Milestone MS19 by liaising with the workshop organisers (UGOT, LU), actively participating in the workshop and contributing to its outcome.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 10-LU_UGOT

Beneficiary (10) LU_UGOT contributed to Milestone MS19 by organizing and actively participating in the planned workshop and contributing to its outcome.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 10-LU_MET

Beneficiary (10) LU_MET contributed to Milestone MS19 by liaising with the workshop organisers (UGOT, LU), actively participating in the workshop and contributing to its outcome.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.4 by beneficiary 10-LU_UUPP

Beneficiary (10) LU_UUPP contributed to Milestone MS19 by attending the workshop in Skogaryd and Uddevala, Sweden, March 2018 (Anna Rutgersson and Antonin Verlet-Banide).

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.4 by beneficiary 8-NERC_UoE
Beneficiary (8) NERC_UoE's activitiy in T1.4 has not started yet. When the instrument for fCO2 observations is being trialled (in a few months' time), some of these trials will be in river and estuary environments, and will show how ICOS can contribute to the technology to enable assessment of dissolved carbon transportation in these systems. For this reason, one PM in developing and testing this system is allocated to task 1.4.

Description of work carried out in T1.4 by beneficiary 8-NERC_PML

Beneficiary (8) NERC_PML: activity has not started yet

Description of work carried out in T1.4 by beneficiary 12-UAntVLIZ

Beneficiary (12) UAnt_VLIZ: activity has not yet started in this task

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

Beneficiary (11) ETHZ has not yet started activity in this task.

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

Task leader: (4) UVSQ
Beneficiaries involved in T1.5.: (3) UNITUSINRA, (7) RUG, (24) UBremen, (8) NERCUoE, (12) UAnt, (26) BIRA.

Task 1.5 tackles several aspects of ICOS RI's readiness to provide comprehensive ground-validation of remote sensing products and to further develop algorithms used in remote sensing applications. It unites satellite applications from each of the three observational networks.

Subtask 1.5.1, led by UVSQ, is about integrating TCCON into ICOS, by evaluating the scientific opportunity, the technical feasibility, and the resources needed to bring TCCON into ICOS and making use of Aircores (in relation with Task 3.1) for QC purposes.
Subtask 1.5.2 aims at implementing space-based estimation of air-sea gas-exchange parameters through a so-called FluxEngine toolbox.
Subtask 1.5.3 investigates the potential use of terrestrial laser scanning (TLS) at the ICOS ecosystem stations.

Within the reporting period progress was made by (1) outlining a paper on "Scientific and technical concept for the integration of European TCCON sites into ICOS and resulting costs", (2) by improving the FluxEngine toolbox for easy installation on various computer systems and (3) by planning field campaigns to validate the TLS measurements.

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
MS8	TCCON and ICOS data integration workshop held	WP1	24 – Ubremen	12	TCCON and ICOS data integration workshop held
MS18	Pilot retrieval of the satellite data for surface temperature (SST), skin effects, wave state and wind speeds developed	WP1	8 – NERC	18	Pilot retrieval of the satellite data for surface temperature (SST), skin effects, wave state and wind speeds developed
MS20	TCCON and ICOS technical integration workshop held	WP1	4 - UVSQ	18	TCCON and ICOS technical integration workshop held

Description of work carried out in T1.5 by beneficiary 4-UVSQ

Beneficiary (4) UVSQ contributed to Milestones MS8 and MS20
In order to begin the process of bringing the TCCON and ICOS communities closer together, a first session to develop the concept of integration between both communities took place during ICOS MSA (21-23 November 2017 / Groningen) on Wednesday 24 November 2017 in "Session 4. Total column/vertical profile measurements". Four talks were presented during this session; material is available upon request to UVSQ:

1. Towards integration of TCCON in ICOS (Thorsten Warneke, UBremen).
2. Measurement of greenhouse gases and other climate relevant species using in situ and FTIR remote sensing at Ile de La Réunion (Minqiang Zhou, BIRA).
3. Calibration of FTIR using AirCore (Huilin Chen, RUG).
4. Low resolution FTIRs (Mahesh Sha, BIRA).

This session validates the milestone MS8 - "TCCON and ICOS data integration workshop held" (due in M12) done in M11.

In parallel with this work of bringing the two communities together, a concept paper is being edited. Outlines of "Scientific and technical concept for the integration of European TCCON sites into ICOS and resulting costs" are done. The draft of the concept paper is now circulating between partners, and the final version is expected for M30. In particular, it has been decided that the concept paper will focus on TCCON for long-term monitoring and for satellite validation, optional centralized processing and centralized QA/QC for a European TCCON hub; special attention will further be given to documenting TCCON data flow. This will help define which part of the processing goes to TCCON Thematic Center (TTC), and relations between station PIs and TTC.

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

Deviations from the implementation of task

No major deviations from the DoA for subtask 1.5.1.

The milestone “TCCON and ICOS technical integration workshop” - MS20 due in M18 is delayed to M21, to be held during the third ICOS Science Conference, organized in Prague, Czech Republic from Tuesday 11th to Thursday 13th September 2018. As the ICOS Science Conference hosts a session on the special theme #11 "In situ and remote sensing observations", and is preceded by the ICOS Monitoring Station Assembly (Monday, 10 September), it is therefore legitimate to reduce the travel of stakeholders, and take advantage of its audience to bring together a greater number of representatives of the ICOS and TCCON communities. This delay of 3 months for MS20 will not affect the full implementation of task 1.5.1.

Deviations from the planned use of resources

No deviation from the planned use of resources

Unforeseen subcontracting (if applicable)

No unforeseen subcontracting

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

No unforeseen use of in kind contribution from third party

Description of work carried out in T1.5 by beneficiary 7-RUG

Beneficiary (7) RUG contributed to Milestone MS8 by evaluating the calibrations of TCCON total column retrievals and by validating the new vertical profile retrievals from two TCCON sites. Based on the ongoing AirCore observations since 2013 at the TCCON Sodankylä site, RUG has evaluated the TCCON calibration factors for CO_2, CH_4, and CO for a single site.

Besides this, RUG organized an intensive AirCore campaign in Sodankylä in June 2018, with the objectives to develop the readiness of AirCore launches in multiple member states (Switzerland, Germany, France, Netherlands, Finland) in Europe. A second AirCore campaign is scheduled in Trainou in the spring/summer 2019, where we expect to further improve the AirCore technique based on the improvements/lessons we gained in the first intensive campaign.

In addition, two teams from NOAA and UEA participated in the campaign on a voluntary basis and will compare their AirCore profiles with those from RINGO partners.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from implementation plan

Deviations from the planned use of resources

No deviations from planned resources

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.5 by beneficiary 24-Ubremen

Beneficiary (24) UBremen contributed to Milestones MS8 and MS20.
One main aim is the development of the concept for a potential integration of TCCON in ICOS. This concept will be documented in a concept document, which will be produced during the project.
University of Bremen and BIRA have conducted the following activities towards the current draft of the concept document.

a) November 2017: Presenting initial ideas for the role of TCCON in ICOS during the ICOS MSA-meeting in Groningen
b) December 2017: Preparation of an initial draft of the concept paper based on the feedbacks during the ICOS-MSA meeting
c) January 2018: Conducting a phone conference with ICOS representatives to discuss the draft concept
d) March 2018: Presenting the ideas during the RINGO annual meeting in Antwerp
e) June 2018: Present the integration plan during the annual TCCON meeting in Mexico to the non-European TCCON community and having a breakout meeting about the integration concept.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from implementation plan

Deviations from the planned use of resources

The work conducted up to now has been funded by institutional funding of the University of Bremen and not by the RINGO project. This had internal reasons. It was the only way to secure positions over the full duration of the project.

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T1.5 by beneficiary 8-NERC_UoE

Beneficiary (8) NERC_UoE contributed to Milestone MS18.
The FluxEngine toolbox has been overhauled to allow simple installation on Apple Mac, Linux, and Windows computers along with verification tools and data to allow the user to easily confirm that the software has been installed correctly (the toolbox can now be easily used at the project training workshop). This has included altering the internal structure of the toolbox, so that it is now easier to add and extend the toolbox to include new functions, such as additional air-sea gas parameterisations and download functions to address MS18. We are now in a good position to start extending the FluxEngine toolbox to address Milestone MS18. This required the publishing of a verification dataset to allow us to easily verify the toolbox calculations as we extend the toolbox to address MS18 (Holding et al., 2018). These extensions will also make it very easy for all other partners to run the toolbox on a laptop so that they can easily calculate gas fluxes from their in situ data.

Holding T, Ashton IGC, Woolf D, Shutler J (2018). FluxEngine v2.0 and v3.0 reference and verification data, Pangaea, 10.1594/PANGAEA.890118

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
No deviations from planned use of resources
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.5 by beneficiary 12-Uant

The goal of task 1.5.3 is to investigate the potential use of terrestrial laser scanning (TLS) at the ICOS ecosystem stations. Terrestrial Laser scanning has a great potential to improve aboveground biomass estimations at the ecosystem forest station in ICOS. This task will test if the volume estimates reach the requested accuracy to be applied within the ICOS network.

The deliverable (D1.7) for this task is only due in month 42. However, the activities have already started since month 7. A PhD Student (ir. Miro De Mol) was hired on the project. For this project, there is intense collaboration with the CaveLab research group (www.ugent.be/bw/temb/cavelab) at the University of Ghent that has expertise in Terrestrial Lidar Scanning. During the first six months, the student became acquainted with the research topic and started with the planning of a field campaign to validate the TLS measurements. Thereafter, a protocol was drafted to perform the TLS measurements at the study sites as part of the deliverable D1.7. During the first field campaign 60 trees were scanned with TLS and destructively harvested at four different sites in Belgium covering three different species. Each tree was cut and every segment (trunk, first order branches and second order branches) was weighted separately. In addition, stem segments and cores were taken from each tree to determine the wood density, needed to convert weight into volume. All field data was processed and volume at tree level were determined. The next six months will be used to process the TLS data.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
The originally anticipated 12PM for a senior researcher (Post-doc) were converted into 23PM for a junior researcher (PhD-student). The total budget of the task remains however unchanged. This change has also no implication on the foreseen work plan and deliverables. It has been agreed with the coordinator and Project officer (Please refer to section 6 for more specific details).
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
The initially budgeted 12PM (senior researcher) are converted into 23PM (junior researcher).
9000 Euro are transferred from consumable to salary.
Unforeseen subcontracting (if applicable)
Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T1.5 by beneficiary 26-BIRA

Beneficiary (26) BIRA contributed to Milestones MS8 and MS20.
As reported by beneficiary UBremen, BIRA worked together with UBremen on the development of the concept document for the integration of TCCON in ICOS. It contributed actively to the associated discussions that were held with the TCCON and ICOS communities and to the workshops where the concept ideas have been presented and discussed.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA, besides the planned resources
Deviations from the implementation of task
No deviations from the implementation plan
Deviations from the planned use of resources
In the original plan, resources were allocated to the organisation of a workshop to discuss the integration of TCCON in ICOS. Since this workshop was replaced by a dedicated presentation with discussion followed by a breakout meeting during the TCCON annual meeting in Mexico, these resources have been partially transferred to travel costs for this meeting in Mexico; these changes have been agreed with the coordinating team (please refer to section 6 for more specific details).
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Work Package 2: Enhancing ICOS membership and sustainability

Lead Beneficiary: (6) UVGZ
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.

The work carried out in WP2 during the first reporting period (M1–M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

Contributions per task:

Task 2.1: Enhancing ICOS membership and sustainability

Task leader: 1- ICOS ERIC

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

D2.2 Concept document on collaboration with countries and stations outside European Union (M12)

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
MS9	Concept document on collaboration with countries and stations outside European Union	WP2	6 - UVGZ	12	Concept document on collaboration with countries and stations outside European Union
MS21	First draft of report on enhancing membership strategy for ICOS ERIC to be discussed in ICOS ERIC bodies	WP2	6 – ICOS ERIC	18	First draft of report on enhancing membership strategy for ICOS ERIC to be discussed in ICOS ERIC bodies

Description of work carried out in T2.1 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC contributed to D2.2:
ICOS ERIC wrote the concept document on collaboration with countries and stations outside European Union. This document will be utilized in further development on the strategy towards potential member countries.

ICOS ERIC contributed also to the questionnaire addressed to ICOS candidate countries, led by UVGZ, that gave perspective for the needs of new potential member countries and was utilized in the concept document. Beneficiary (1) ICOS ERIC contributed to Milestone MS21 by designing a questionnaire on the ICOS strategy targeted to the RI Committee members. The strategy towards new countries and increasing engagement was discussed in the RI Committee face-to-face meeting in Heidelberg in March 2018 and further elaborated according to the viewpoints presented by the RI Committee members. The membership strategy is a part of the overall long-term strategy of ICOS RI that was discussed at the ICOS General Assembly in May 2018.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
There was a slight deviation from the DoA on submitting the deliverable, that was delayed with one month due to changes in personnel and re-directing work resources.
Deviations from the implementation of task
N/a
Deviations from the planned use of resources
N/a
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

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

Task leader: (6) UVGZ;
Beneficiaries involved in T 2.2: (13) INOE, (14) OMSZ, (15) ULP, (16) NOA, (17) NUID UCD, (18) EULS, (19) ISA, (20) WITS, (21) PULS

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

D2.3 Initial joint training (including gender issues related training) for research infrastructure managers (PIs) and other relevant stakeholders of the ICOS candidate countries (M18) and tailor-made trainings for the ICOS candidate countries throughout the project duration focused on important managerial and funding issues connected with the ICOS research infrastructure establishment and membership. (M42).
D2.4 Online platform as part of ICOS webpages including technical and scientific training material. (M12)

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
MS10	Virtual training platform available for upload of e-learning material	WP2	6 - UVGZ	12	Virtual training platform available for upload of e-learning material
MS11	Initial workshop on manager training for new countries held	WP2	6 - UVGZ	12	Report available

Description of work carried out in T2.2 by beneficiary 6-UVGZ

Beneficiary (6) UVGZ contributed to D2.3 as task leader by the following:
As a preparation for the initial training needs, a questionnaire addressed to ICOS candidate countries was developed in collaboration with ICOS ERIC Head Office. The questionnaire among others collected relevant contacts on 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 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 Head Office online (EMDESK) tool and presented and discussed with the RINGO participants at the Brno Initial RINGO training (see more below in description of work in T2.2, D2.4, T2.3 and D2.5) and at the ICOS GA Antwerp meeting in March 2018. The questionnaire was utilized further in MS9 and MS21, where the outcomes were used as one input source in the draft report on enhancing membership strategy for ICOS ERIC.

In order to ensure the building of national networks in ICOS candidate countries, a two-day initial training for managers and other relevant stakeholders of these countries was organised by UVGZ in the Czech Republic in UVGZ headquarters and UVGZ research infrastructure on 13–14 September 2017. The training covered the main important contractual, managerial and funding issues connected with the ICOS research

infrastructure establishment and membership. The scope of the initial training focused mainly on financial, administrative and management tools and resources such as EU structural funding and potential solutions with the European Investment Bank (EIB), complementary Horizon 2020 and other programming (e.g. Joint programming, ERA-NETs, EEA). The training was organised by WP2 leader UVGZ in cooperation with the ICOS bodies (mainly ICOS Head Office). Training materials were uploaded to a virtual training platform.

Beneficiary (6) UVGZ contributed to D2.4 as task leader by the following:
A virtual training platform available for upload of e-learning material was launched in April 2017 by ICOS Head Office using the EMDESK platform, where all actual information and e-learning materials related with WP2 activities are uploaded by UVGZ. Part of the documents, especially research infrastructure project applications and evaluation reports, have sensitive character (e.g. project know-how, scientific ideas) in a competing environment with other assessed research infrastructures for long-term funding. This is why the EMDESK platform has been selected as the most suitable platform to keep the confidentiality of the shared documents among the project partners.
Particular needs related to the diverse maturity of the ICOS candidate countries has been considered and the most appropriate information for research infrastructure development has been provided during the course of the project. During the initial training that was organised in the Czech Republic, the example of the UVGZ experience with European Structural Funds and the national ICOS establishment was directly showcased to ICOS candidate country representatives, including showcase of key parts of ICOS Czech Republic infrastructure. Documents from the training where shared electronically among the training participants. Other materials and guidance related to the issues that are relevant for the ICOS candidate countries such are for example RI human resources topic (e.g. HRS4R agenda), RI open access management, public aid issues towards RIs, responsible research and innovation issues related to RIs have been prepared to be published in English. Because of the time and content context, it will be published in one package in autumn 2018 after discussion and feedback from the ICOS candidate partners and other RINGO participants during the ICOS Scientific Conference (Prague, September 2018).

Due to different phases in national infrastructure roadmap development, national funding procedures or EU structural funding, it was necessary to prepare a tailor-made approach prior to this initial training. Works on this started in the RINGO project kick-off meeting in February 2017 and continued mainly during the spring and summer 2017 by the elaboration of a questionnaire focused on the various issues related to ICOS candidate countries national infrastructure development. UVGZ prepared the questionnaire, processed the filled questionnaires and organised the discussion of the questionnaire outcomes, as well as the online publication of the filled questionnaires (EMDESK project tool). UVGZ presented and discussed in collaboration with ICOS ERIC Head Office with the RINGO participants at the Brno Initial RINGO training and at the ICOS GA Antwerp meeting in March 2018. Summarised and updated outcomes of these activities will be published on EMDESK in autumn 2018 together with the published training package (see paragraph above).

As a European research infrastructure, ICOS is committed to further develop its gender balance and the involvement of early career scientists. To support this development, an extra part of the initial training focused on gender balance in research teams and capacity-building, considering the special needs of early career development. The training was provided by an external expert (Hana Víznerová, National Contact Centre - Gender & Science) on gender issues. The training material on the topic was published on EMDESK.
During the course of the project, mainly UVGZ, ICOS Head Office and ICOS central facilities and thematic centres ensured continuous provision of tailor-made consultations and lessons (mainly via online communication) 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, OMSZ consulted with UVGZ on the preparation of a national research infrastructure consortium agreement and consulted with ICOS on atmospheric research infrastructure issues at the ICOS Atmospheric Monitoring

Station Assemblies in 2017 (Lund, Sweden, 14–16 March, 2017; Groningen, the Netherlands, 21–23 November, 2017). ISA participated in the 5th ICOS ERIC General Assembly (17.11.2017, Brussels, Belgium) and thanks to WP2 activities ISA acknowledges RINGO project for contribution to enlarge and fortify the national ICOS network in Portugal, including a new research area (flux measurements in inland water bodies). RINGO partners from Portugal and Estonia discussed various technical, managerial and administrative issues with ICOS experts and representatives including UVGZ at the 6th ICOS General Assembly meeting, (29–31.5.2018, Bergen).

In spring 2018 started INOE bilateral consultation with UVGZ focusing on the issues related to the establishment of a wetland ecosystem monitoring site to be ready to be constructed according to the ICOS technical and scientific standards with EU structural funding for Romania. With Romanian partners were consulted also research infrastructures on collocation issues (in case of Romania RI ICOS, RI DANUBIUS, RI ACTRIS) during the course of the project and also during the RI DANUBIUS meetings.
Some of these provided consultations are also reported below from the individual RINGO participant perspective.
Beneficiary (6) UVGZ contributed to Milestone MS10 by preparation and upload of the training and e-learning materials and other documents relevant to ICOS candidate countries to online platform provided by ICOS ERIC Head Office.
Beneficiary (6) UVGZ contributed to Milestone MS11 by hosting and organizing the initial workshop in collaboration with ICOS ERIC Head Office in the Czech Republic on 13–14 September 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
no deviations from the DoA
Deviations from the planned use of resources
no deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 13-INOE

Beneficiary (13) INOE contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (13) INOE contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
Deviations from the planned use of resources
Unforeseen subcontracting (if applicable)
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Description of work carried out in T2.2 by beneficiary 14-OMSZ

OMSZ consulted with UVGZ on the preparation of a national research infrastructure consortium agreement and consulted with ICOS on atmospheric research infrastructure issues at the ICOS Atmospheric Monitoring Station Assemblies in 2017 (Lund, Sweden, 14–16 March, 2017; Groningen, the Netherlands, 21–23 November, 2017).

Beneficiary (14) OMSZ contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (14) OMSZ contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
no deviations from the DoA
Deviations from the planned use of resources
no deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 15-ULP

Beneficiary (15) ULP contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (15) ULP contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 16-NOA

Beneficiary (16) NOA contributed to D2.3 by participating in the initial training in Prague 13–14 September 2017. Participants were Pavlos Zarbas and Athina Kalogridi.
Beneficiary (16) NOA contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Beneficiary (16) NOA contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials
and to MS11 by participation of Pavlos Zarbas and Athina Kalogridi in the RINGO initial training organised in Brno (CZ) on 13–14 September 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 17- UCD

Beneficiary (17) NUID UCD contributed to D2.3 by participation in Amanuel Gebremichael in the RINGO initial training organised in Brno (CZ) on 13–14 September 2017.
Beneficiary (17) NUID UCD contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (17) NUID UCD contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials
and to MS11 by participation of Amanuel Gebremichael in the RINGO initial training organised in Brno (CZ) on 13–14 September 2014.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA'
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 18-EULS

Beneficiary (18) EULS contributed to D2.3:
The main objectives of Estonian University of Life Sciences (EULS) is to support the building a national network and training for managers in stakeholder liaison and resource acquisition (task 2.2). There are several activities in Estonia to build up an ICOS Estonia network including also the other universities and research groups that deal with GHG data in Estonia. EULS participated in meetings and workshops organised in RINGO. These activities aim to maintain both scientific and technical contact with the ICOS community

and to build the national network of monitoring that will provide the ground observation of ecosystems GHG budgets. Within the national roadmap application 2018, EULS has applied to join the consortium of the Estonian Environmental Observatory to ICOS (results of this application are pending).
Steffen Noe participated in the 6th ICOS General Assembly meeting (29–31.5.2018, Bergen), where he presented to representatives of ICOS member countries and ICOS Central Facilities the current state of the Portuguese and Estonian preparation for ICOS membership. Various technical, managerial and administrative issues where discussed with ICOS experts and representatives. In the General Assembly meetings, the candidate countries get first-hand information on the operations of ICOS and learn the management and decision-making processes.

Estonian University of Life Sciences participated in the RINGO kick-off meeting that was organized by the University of Heidelberg, Germany (21–23.03.2017) (Steffen Noe). Two PhD students, Alisa Krasnova and Dmitrii Krasnov, participated in the ICOS Summer School 2017 in Hyytiälä, Finland (25.05–01.06.2018). Steffen Noe participated in the RINGO annual meeting in Antwerpen (19–23.03.2018).

Beneficiary (18) EULS contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (18) EULS contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA'
Deviations from the implementation of task
No deviations from the DoA'
Deviations from the planned use of resources
No deviations from the DoA'
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 19-ISA

Beneficiary (19) ISA contributed to D2.3:
ISA participated in the 5th ICOS ERIC General Assembly (17.11.2017, Brussels, Belgium) and thanks to WP2 activities ISA acknowledges RINGO project for contribution to enlarge and fortify the national ICOS network in Portugal, including a new research area (flux measurements in inland water bodies). In the General Assembly meetings, the candidate countries get first-hand information on the operations of ICOS and learn the management and decision-making processes. Beneficiary (19) ISA contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (19) ISA contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA

Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 20-WITS

Beneficiary (20) WITS contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (20) WITS contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.2 by beneficiary 21-PULS

Beneficiary (21) PULS contributed to D2.3:
Bogdan Chojnicki and Damian Józefczyk participated in the RINGO initial training organised in Brno (CZ) on 13–14 September 2014.
Bogdan Chojnicki took a part in the ACTRIS Poland meeting that was held at Institute of Geophysics Polish Academy of Sciences in Warsaw (6.10.2017) where he presented the RINGO project and related ICOS Poland activities such as inter alia the collocation of ICOS and ACTRIS infrastructures. In the meeting was discussed and shared the experience of ICOS and ACTRIS research infrastructure collocation presented in the RINGO initial training by UVGZ.
Beneficiary (21) PULS contributed to D2.4 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
Beneficiary (21) PULS contributed to Milestone MS10 by registration and participation in on-line training platform EMDESK, use of the provided training materials.
and to MS11 by participation of Bogdan Chojnicki and Damian Józefczyk in the RINGO initial training organised in Brno (CZ) on 13-14 September 2014.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA'
Deviations from the implementation of task
No deviations from the DoA

Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Task 2.3: Training workshops for scientists in candidate countries

Task leader: (6) UVGZ;
Beneficiaries involved in T 2.3: (1) ICOS ERIC, (2) UiB, (3) UNITUS, (4) UVSQ, (13) INOE, (14) OMS, (15) ULP, (16) NOA, (17) NUID UCD, (18) EULS, (19) ISA, (20) UWWR, (21) PULS.

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

D2.3 Initial joint training (including gender issues related training) for research infrastructure managers (PIs) and other relevant stakeholders of the ICOS candidate countries (M18).
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. (M42)
NB. D2.5. was partly delivered during the first year of the project. Therefore D2.5 is included in the first interim report. Detailed explanation regarding the work carried out within this reporting period will be presented here, and an updated description will be provided in the following report.

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
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 during first reporting period

Description of work carried out in T2.3 by beneficiary 6-UVGZ

The work in this task has started towards the D2.5 (M42) by organising the first of three scheduled RINGO summer schools.
Beneficiary (6) UVGZ contributed to D2.5 [note that D2.3 is reported above in Task 2.2] 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 first RINGO summer school that was organised by ICOS Carbon Portal in collaboration with the Central Facilities in Finland in Hyytiälä research station 24 May – 2 June 2017. The training participants where mainly PhD students who are involved in the scientific and technical part of the construction and operation of the RI National Networks. These activities have been open also 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 effective transfer of the expertise and contributes to the scientific readiness of the ICOS candidate countries and to the future

technical and scientific cooperation. 8 PhD students participated from ICOS candidate countries. UVGZ reflected the outcomes of the training school, based mainly on the report of the summer school and discussions with some trained participants and representatives of the participating institutions, for the purposes of the next RINGO trainings and initial RINGO training as well. In collaboration with Carbon Portal partners will be published by UVGZ on EMDESK training materials related with the school (it will be published together with other training materials in one package in autumn 2018, see above in T2.2). The summer school experience within the presentation of the RINGO project was presented at the international conference Day of National Research Infrastructures 2017 (Session II: Long-term sustainability of research infrastructure) on 2.11.2017 in Brno, CZ.

Beneficiary (6) UVGZ contributed to Milestone MS33 by organisational contribution (mainly dissemination and communication with W2 RINGO participants) of the first RINGO summer school that was organised by ICOS Carbon Portal in collaboration with the Central Facilities, in Finland in Hyytiälä ICOS research station 24 May - 2 June 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC contributed to D2.5 and MS33 by the following:
The 4th ICOS Summer School took place between 24 May and 2 June 2017 at the Hyytiälä Forestry Field Station, in Finland. Local hosts were Timo Vesala and Olli Peltola, with assistance by Elisa Halmeenmäki, one of the students of the Summer School.

The school handled almost all relevant aspects of carbon cycle science in the context of global climate change, organized as lectures and practical exercises. One session of two half-days was oriented on practical measurements using relatively simple sensors for measurement of temperature, humidity and CO_2 concentrations. The second session of two afternoons was oriented on hands-on experiments with (global) transport models. The school was mainly oriented to PhD students, but several PostDocs and master students preparing to begin a doctorate were also accepted.
From the 37 students 18 were male and 19 female. 8 students were from ICOS candidate member countries, 4 from non-ICOS countries.

The lecturers at the summer school were: Christoph Gerbig (through Skype), Martin Heimann, Maarten Krol, Anders Lindroth, Greet Maenhout, Alex Vermeulen, Wouter Peters, Kadmiel Maseyk and Timo Vesala. Olli Peltola and Elisa Halmeenmäki were important (local) organisers and assisted the students and teachers during the practical exercises. Aki Tsuruta assisted during the modelling practical on May 31.
Poster abstracts: All students presented a poster and an elevator pitch on the first day. The poster session was well received and students and lecturers had good and lengthy discussions around the poster boards.

The 4th ICOS Summer school was endorsed by the European projects ENVRIplus, COOP+ and RINGO. The summer school website can be found on the web at http://2017.icos-summerschool.eu.
A total of 30 students filled in the evaluation form of the summer school. 18 students provided written comments, that are mostly very helpful for a follow-up summer school. The overall evaluation on a scale of 1 to 6 was 4.9 (± 0.5), which would correspond to 8.1 on a scale of 1 to 10. This is very positive and slightly higher than evaluations of previous editions of the summer school. The 2011, 2013 and 2015 TTorch Summer Schools received scores several tenths lower. From the evaluation, it is clear that, in the next version of the Summer School, the practical exercises on measurements should receive more attention and are in need of significant improvement.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 2-UiB

Beneficiary (2) UiB will contribute to the T2.3 in later part of the project.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 3-UNITUS

Beneficiary (3) UNITUS contributed to D2.5 and MS 11 by engaging in discussions on the organization of the training

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task

No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 4-UVSQ

Beneficiary (4) UVSQ's activity has not yet started in this task.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 13-INOE

See activity reported above.

Description of work carried out in T2.3 by beneficiary 14-OMSZ

See activity reported above.

Description of work carried out in T2.3 by beneficiary 15-ULP

Beneficiary (15) ULP contributed to D2.5 by participation of María Rosario Moya Jiménez, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.
Beneficiary (15) ULP contributed to Milestone MS33 by participation of María Rosario Moya Jiménez, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 16-NOA

See activity reported above.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 17- UCD

Beneficiary (17) NUID UCD contributed to D2.5 by participation of Teresa Spohn, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.
Beneficiary (17) NUID UCD contributed to Milestone MS33 by participation of Teresa Spohn, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 18-EULS

Beneficiary (18) EULS contributed to D2.5 by participation of Alisa Krasnova, PhD student, and Dmitrii Krasnov, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.
Beneficiary (18) EULS contributed to Milestone MS33 by participation of Alisa Krasnova, PhD student, and Dmitrii Krasnov, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

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

No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 19-ISA

Beneficiary (19) ISA contributed to D2.5 by participation of Carla Nogueira, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a
Description of work carried out in T2.3 by beneficiary 20-WITS

See activity reported above.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T2.3 by beneficiary 21-PULS

Beneficiary (21) PULS contributed to D2.5 by participation of Kamila Harenda, PhD student, and Mateusz Samson, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

Beneficiary (21) PULS contributed to Milestone MS33 by participation of Kamila Harenda, PhD student, and Mateusz Samson, PhD student, in the 4th ICOS Summer School Hyytiälä, Finland, 24 May – 2 June 2017.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Work Package 3: Technical developments

Lead Beneficiary: 9 – UHEL

The main objective of WP3 is to explore the technological necessities to enable the scientific concepts developed in WP1. It comprises technical pilot studies or workshop-based conceptual studies that will provide clear guidance for further technical innovations within ICOS.
The budget of the proposal is too small to enable highly desired investments into the network infrastructure. However, the results will improve the sustainability of ICOS by providing a clear perspective for this to stakeholders and funding organisations.
The work carried out in WP3 during the first periodic reporting period (M1–M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary:

Contributions per task:

Task 3.1: Exploration to apply new technologies for vertical profiles

Task leader: 7-RUG
Beneficiaries involved in T3.1: 4-UVSQ, 25-GUF, 24-UBremen, 9-UHEL_FMI, 11-ETHZUBern, 26-BIRA
.
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
MS12	High accuracy in situ vertical profile measurements started	WP3	7 - RUG	12	High accuracy in situ vertical profile measurements started

Description of work carried out in T3.1 by beneficiary 7-RUG

RUG took the lead in organizing the scientific part of AirCore development and the first intensive campaign in Sodankylä, and together with our partner FMI to organize the logistical part of the first intensive campaign

(MS12). Among the 7 partners within Task 3.1, five groups work on AirCore observations, and two groups work on development of vertical profile retrievals using TCCON spectra data.
Here is a summary of the major achievements in the reporting period:
1. Laboratory testing and improvement of AirCore measurements
Laboratory slug tests were performed for multiple AirCores, where gases from two cylinders with distinct mole fractions of CO_2, CH_4, and CO were alternately flushed through the AirCores and were then analyzed by a cavity ring-down spectrometer. As an example, the test results of CO_2 are shown as a function of the volume of air (ml) flushed since the start of the change of air for five AirCores (see Figure 8).

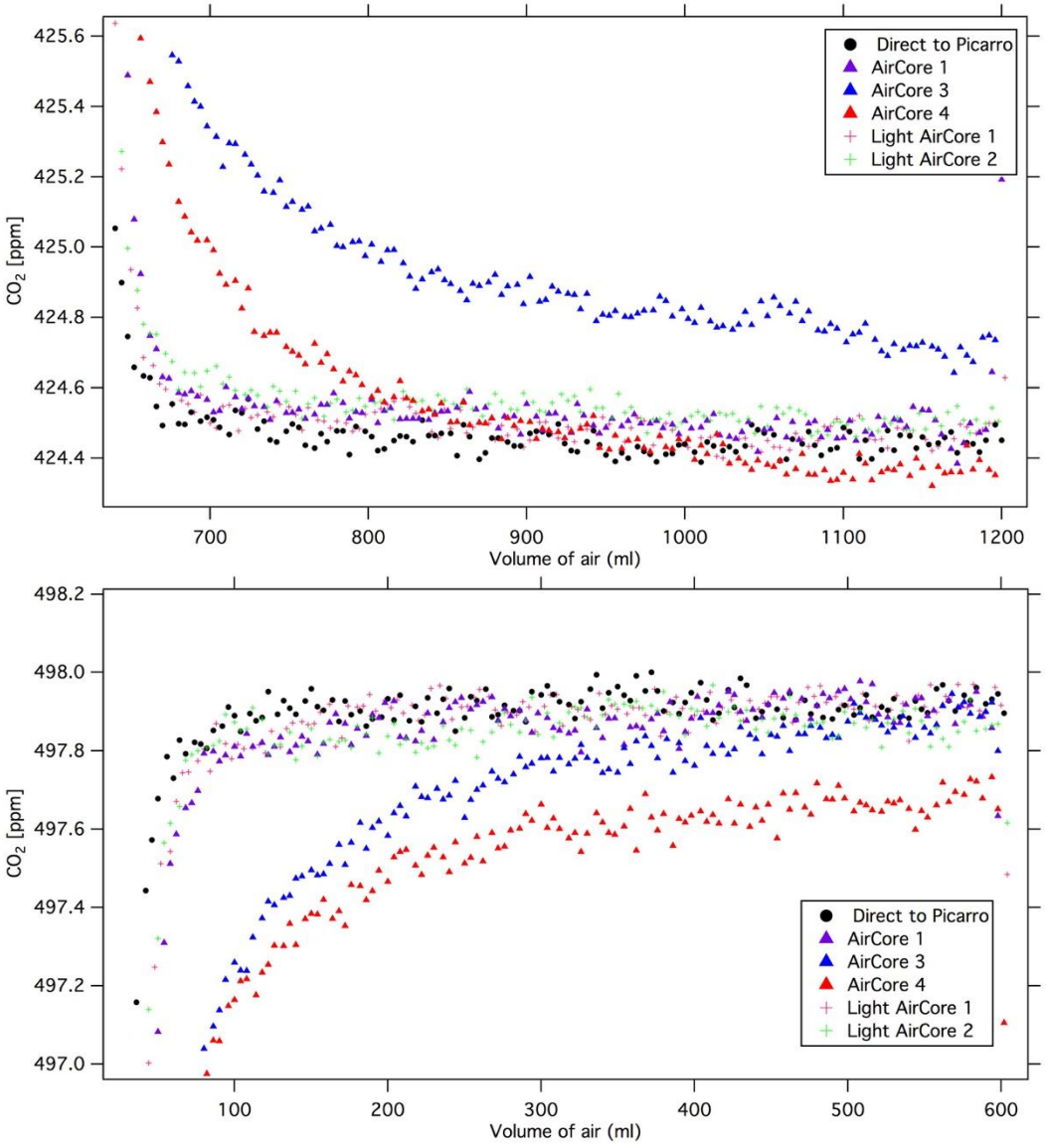

Figure 8. Slug test results of CO_2 as a function of the volume of air (ml) flushed since the start of the transition from high to low mole fractions (top) and from low to high mole fractions (bottom) for five AirCores.

We found that the transition of AirCores 3&4 was slower than that of other AirCores, indicating problems with these two AirCores. Therefore, we let the two AirCores 3&4 re-coated with SilcoNert 1000 by Restek Inc. With the new coating, AirCores 3&4 performed as good as the others.
2. Establishment of AirCore pre-flight criteria

Based on the slug test results, we have established the AirCore pre-flight criteria, i.e. these must be reached before being part of the comparison flights. The criteria were established for CO_2, CH_4, and CO, respectively (see Table 1).

Table 1. the AirCore pre-flight criteria based on the results of slug tests, the thresholds for the difference between the slug and direction measurements are presented for the certain flushing volume of air (in ml).

	CO_2	CH_4	CO
± Compared to direct measurement	0.1 ppm	1ppb	5ppb
Stable after switch	120 ml	110ml	100ml

3. Preparation of the AirCore comparison flight plan

Considering the constraints on the weather conditions, logistics of recovery and sample analysis, we have planned the comparison flights on five days within a two-week campaign period, with two flights per day, and three AirCores/LISA sampler per flight (see Table 2).

Table 2. the comparison flight planning of the first intensive campaign in Sodankylä, Finland.

	Day 1	Day 2	Day 3	Day 4	Day 5
1	RUG LISA	NOAA	GUF	UBERN	FMI
	RUG AirCore	RUG LISA	RUG LISA	NOAA	RUG
	UBERN	LMD	UEA	GUF	Ozonesonde
2	LMD	UBERN	RUG AirCore	RUG LISA	
	GUF	UEA	NOAA	FMI	
	UEA	RUG AirCore	LMD	Ozonesonde	

4. Coordination of the first intensive campaign in Sodankylä

A total of 10 AirCore flights were made, including direct comparisons on the same flight, or on two separate flights. We have also organized a round-robin comparison of cylinders to make all measurements on the same scale.

The data analyses by each partner are in progress, and we will collect all AirCore analysis results and make the comparisons. They are expected to reveal issues of AirCore measurements and enable us to develop guidelines to improve the AirCore technique.

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

The first intensive campaign in Sodankylä was delayed by ~6 months, because there is no sunlight in Sodankylä in winter.

Deviations from the implementation of task

No deviations from the DoA

Deviations from the planned use of resources

No deviations from the DoA

Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T3.1 by beneficiary 4-UVSQ

Beneficiary 4-UVSQ contributed to Milestone MS12 by participating to the first field campaign in Sodankylä (June 2018) dedicated to the comparison of five AirCore systems. As scheduled during this campaign we have launched three LSCE/LMD AirCores, similar to the ones used since October 2016 at the ICOS and TCCON station of Trainou, France. The three AirCores have been successfully recovered and analyzed with our CRDS-G2401 instrument for atmospheric concentrations of CO_2, CH_4, CO and H_2O. The two reference cylinders that we used in Sodankylä were also analyzed by the other institutes in order to verify the compatibility of the calibration scales.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T3.1 by beneficiary 25-GUF

Beneficiary 25-GUF contributed to Milestone MS12 by performing AirCore measurements of CO_2, CH_4 and CO in Lindenberg/Germany in June 2017. Two successful flights were performed.
An improved AirCore system has been developed which uses a simplified technique to join tubes of different diameters. For this purpose, new tubings were surface-coated. University Frankfurt then participated in the Sodankylä AirCore intercomparison campaign using both the old and the new AirCore systems.
In preparation of the campaign, University Frankfurt performed a range of tests on the AirCores (slug-test, stability tests and calibrations).

Altitude attribution is a particularly important aspect of AirCore observations. As a further activity for the validation of the AirCore technique, University Frankfurt has therefore started the development of a technique to release pulses of CO during the AirCore sampling to improve the altitude attribution. This method has been tested during the Sodankylä campaign, but the pulsing valve failed due to technical problems. For the pulsing test and the AirCore flights, University Frankfurt participated with 4 persons (Thomas Wagenhäuser, Robert Sitals, Audrey Gaujon and Andreas Engel). The new spiking method under development at University Frankfurt will allow significant improvement in the altitude attribution and will be further pursued.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA

Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.1 by beneficiary 24-Ubremen

As part of the Task 3.1, the University of Bremen is responsible for the demonstration of the retrieval of tropospheric methane (CH_4) from the ground-based TCCON (Total Carbon Column Observing Network) measurements using N_2O as a proxy for stratospheric CH_4. The progress made during the current reporting period is discussed in this section.

TCCON is an international network established in 2004 using ground-based Fourier Transform Infrared (FTIR) Spectrometry for recording direct solar absorption spectra in the near-infrared spectral range and to retrieve from these spectra total column concentrations of atmospheric greenhouse gases (including CH_4) with a high precision. Currently, there are about 25 TCCON sites around the world with latitude coverage from 45°S to 80°N. The standard TCCON retrieval code used is GGG2014 (developed and maintained at JPL, NASA); it performs a profile scaling retrieval, so that the standard TCCON product for CH_4 is the total column averaged CH_4 abundance (XCH_4).
In the framework of the H2020 RINGO project, we employ the method of using N_2O as a proxy for the stratospheric CH_4 and derive the tropospheric column averaged volume mixing ratio of CH_4. The development of this method has been started within the EU project INGOS. It turned out that a thorough understanding of the border between stratosphere and troposphere given by this method is needed. This “chemical tropopause” does not coincide with the common “lapse rate tropopause”. Within RINGO the tropospheric mixing ratio of CH_4 derived from this method will be compared with vertical resolved in situ data and the “chemical tropopause” will be further characterised. This is highly important for using the data, e.g. for model validation. Following this, either this proxy method or the optimal estimation retrieval (see BIRA) will be promoted to be included in TCCON.

Tropospheric XCH_4 retrieval using N_2O as a proxy and comparison with in situ data
The initial development of the N_2O proxy method has been carried out within the EU project INGOS (Wang *et al*., 2014). Within the first phase of the RINGO project, the tropospheric CH_4 derived from TCCON measurements was compared to vertical resolved data, mainly boundary layer aircraft profiles, at several ICOS sites and used for model evaluation (Figure 9, Wang *et al*., 2017).

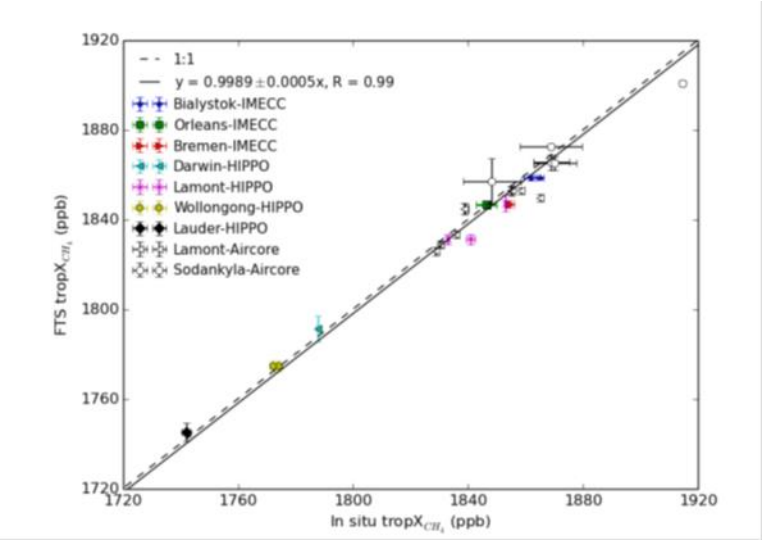

Figure 9. Tropospheric column-averaged CH4 mole fractions derived from TCCON measurements vs. the calculated one from vertical resolved in situ data (Figure from Wang et al., 2017).

This comparison was limited by the small number of in situ profiles extending above the boundary layer. Within RINGO AirCore measurements will become available, especially at Sodankylä and Orleans. The seasonal variation of the tropospheric XCH_4 derived with this method is shown in Figure 10. The variation of the tropospheric CH_4 is much lower than the one for the total column XCH_4.

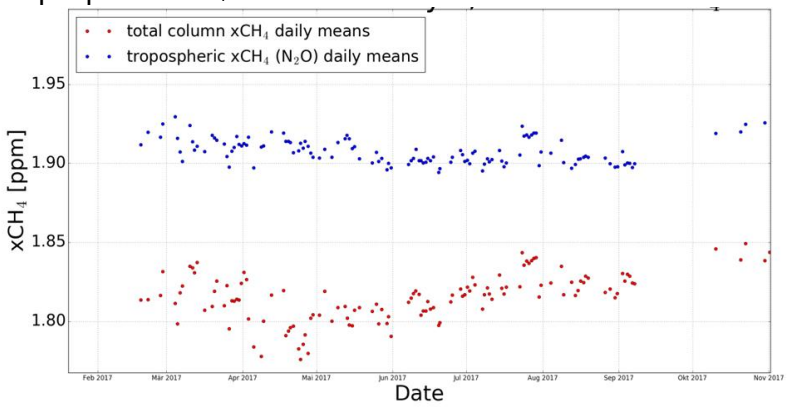

Figure 10. Timeseries for 2017 at Sodankylä. In red the TCCON total column XCH_4 is shown, in blue the tropospheric XCH_4. The seasonal variation for the tropospheric XCH_4 is much lower than for the total column XCH_4.

The retrieved tropospheric column data have been compared to the available AirCore measurements taken at Sodankylä for 2017 (10 days). The agreement of the absolute values is good. However, there is only very little variation in tropospheric CH_4, which limits the use of this data to determine the slope.

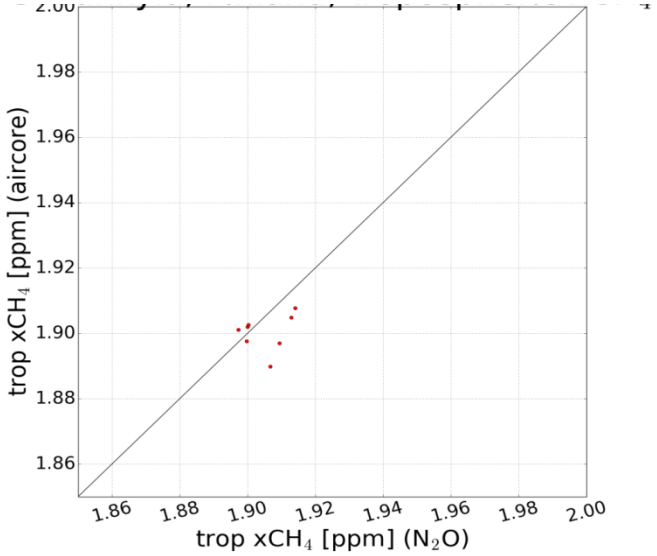

Figure 11. Scatterplot for the days with AirCore measurements for 2017 at Sodankylä. The tropospheric XCH_4 derived with the N_2O method against the AirCore XCH_4.

Outlook and next steps

The AirCore comparison will be continued at Sodankylä. In late 2017 and 2018, AirCore data also became available at Orleans. The 2017 AirCore data at Orleans could not be used due to instrumental problems with the TCCON FTIR spectrometer. However, the 2018 AirCore data at Orleans will allow studying the linearity of the comparison (extension of Figure 11 to a larger range of concentrations). Furthermore, the Sodankylä and Orleans comparisons will be used to study the location of the "chemical tropopause" implicitly used by the proxy method. Finally, an evaluation will be carried out if the optimal estimation retrieval or the proxy retrieval method is more useful and one method will be promoted for implementation in TCCON.

Wang, Z., Deutscher, N. M., Warneke, T., Notholt, J., Dils, B., Griffith, D. W. T., Schmidt, M., Ramonet, M., and Gerbig, C.: Retrieval of tropospheric column-averaged CH4 mole fraction by solar absorption FTIR-spectrometry using N_2O as a proxy, Atmos. Meas. Tech., 7, 3295-3305, https://doi.org/10.5194/amt-7-3295-2014, 2014.

Wang, Z., Warneke, T., Deutscher, N. M., Notholt, J., Karstens, U., Saunois, M., Schneider, M., Sussmann, R., Sembhi, H., Griffith, D. W. T., Pollard, D. F., Kivi, R., Petri, C., Velazco, V. A., Ramonet, M., and Chen, H.: Contributions of the troposphere and stratosphere to CH_4 model biases, Atmos. Chem. Phys., 17, 13283-13295, https://doi.org/10.5194/acp-17-13283-2017, 2017.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the DoA

Deviations from the planned use of resources

No deviations from the DoA

Unforeseen subcontracting (if applicable)

N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Description of work carried out in T3.1 by beneficiary 9-UHEL

Linked Third Party FMI (Finnish Meteorological Institute) contributed to Milestone MS12 by an AirCore field campaign at the Finnish Meteorological Institute site in Sodankylä, Finland, by campaign preparations and by AirCore and other relevant measurements at the site. The work carried out by the FMI included preparations for the AirCore measurements, the campaign execution and data analysis. The Sodankylä site is equipped with TCCON station, facility for the AirCore measurements and a mast for in situ measurements. The RINGO campaign took place June 17 – June 30, 2018. During a two-week period, 23 AirCore profile measurements were obtained. In total we performed 10 research flights, including single and multiple AirCore payloads. The participants of the AirCore Campaign included scientists from the Finnish Meteorological Institute, Groningen University in the Netherlands, University of Bern in Switzerland, University of Frankfurt in Germany, Laboratoire des Sciences du Climat et de l'Environnement in France.
FMI provided campaign infrastructure including balloon facility, laboratory space, Picarro analyser, and calibration gases needed for the AirCore measurements. FMI scientists performed TCCON and AirCore measurements and analysis. FMI also took care of all the payload launches. AirCore analysis were performed in collaboration with RUG. For the AirCore launches FMI provided meteorological balloons, balloon filling gas, parachutes, radiosondes, radiosonde data receiving and processing equipment, transponders needed according to the Air Traffic regulations, payload positioning equipment (GNSS, Iridium, GSM) and other items. Remote sensing TCCON and in situ measurements were also taken at the mast located at the observatory. The in situ mast is about 500 meters from the TCCON and AirCore launch site. Picarro measurements of CO_2, CH_4 and CO were taken at 3 levels: 50 m, 23 m and 2 m from the surface. TCCON measurements were taken on all clear days as they depend on direct solar light.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.1 by beneficiary 11-ETHZ_UBern
Linked Third Party UBern contributed to Milestone MS12 by constructing two new, about 200-meter long AirCores with one single inner diameter of roughly 3 mm. The corresponding volumes are 1300 and 1570 cubic centimeters. Together with an already available AirCore that has been used since 2015, they were in use during the 2018 campaign in Sodankylä in Northern Finland. Before the campaign the AirCores had to pass so-called storage and slug-tests which were all successful for our AirCores.

The campaign took place from Monday, June 18 to Friday, June 29, 2018. The campaign was a great success in that we have performed flights with seven AirCores from Bern on the following dates:

- June, 18 Old AirCore Ringo-1 25'554 m, successful
- June, 21 Old AirCore Ringo-4 23'914 m, flight successful, no air sampled (valve not opened because of error in electronics)
- June, 25 AirCore-1 Ringo-6 28'870 m, successful
- June, 25 AirCore-2 Ringo-7 29'033 m, successful
- June, 25 Old AirCore Ringo-8 34'710 m, successful
- June, 29 Old AirCore Ringo-10 29'916 m, successful

- June, 29 AirCore-2 Ringo-10 29'916 m, successful

On these AirCores we have measured the following concentrations: CO_2, CO, CH_4, H_2O and O_2, and for particular flights also the isotopic composition of O_2, i.e. the $^{18}O/^{16}O$ isotope ratio. We managed to set up two Picarro systems in line (Picarro 2401 and Picarro 2207) with highest stability for both systems using a low flow rate of 27 ml/min in order to get a high spatial resolution for the measured components. The stability was obtained through a pressure controller before the AirCore or bypass and a flow controller at the end of the second Picarro (the Picarro 2207 for O_2).

During the campaign we became aware that the system also allows for an AirCore resampling with a second AirCore. This means that we resampled the air of the first AirCore that was hooked up in front of the two Picarro instruments with a second AirCore placed after the flow controller at the end of the two instruments. This resampled air was then remeasured by the two Picarro to first check its consistency for the Picarro 2401 results. Measured differences are assigned either to diffusion and dispersion of the system as well as contamination by the pump between the two Picarro systems. The latter effect was further investigated in the field at Sodankylä by remeasuring standard air several times with the aforementioned method. Secondly, this resampled air was used to determine the isotopic composition of O_2. For that we switched the method on the Picarro 2207 instrument to the isotope mode. This resulted in significantly less precise O_2 concentration results but with the advantage of yielding isotope values. Yet, the precision of those were rather noisy and require long averaging times of a few minutes to see the real atmospheric variations. Despite these shortcomings, these results are the first of this kind regarding time as well as vertical resolution. This method has been applied to our Ringo flights 6, 7, 8 and 10.

We used this resampling method also to measure the air sampled with the Frankfurt AirCore. For that we hooked up our AirCore-1 and sampled their AC3 AirCore air with a flow rate of 43 ml/min set by Frankfurt measurement system. After this subsampling we measured the AirCore-1 at our system and subsampled it by our AirCore-2 for isotope measurements. Everything went smoothly and we suggest that all groups should apply and further investigate this new methodology. It guarantees complementary measurements without launching an additional AirCore.

Our main intention to perform the flights at Sodankylä was to compare our results with those of other AirCores. Our flights allow comparisons with all participants, i.e. LSCE, UEA, RUG, UHel, UFrankfurt and NOAA. Unfortunately, the direct comparison with NOAA results was not possible since during the Ringo-4 flight the valve of our AirCore was not opened and therefore no air was sampled despite the fact that it went up to the stratosphere.

Additionally, we have worked on the ultimate goal of incorporating the AirCore into a glider system. We already have the glider available but we are awaiting the newest release of the electronics and will then preform the first tests. The new AirCores are built in such way that they fit into the glider. During the next campaign the glider system should be available.

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

Deviations from the implementation of task

Task fully implemented, one key issue requires further attention, i.e. accurate altitude registration of AirCore vertical profiles.

Deviations from the planned use of resources

Costs of campaign not yet represented in this report since it happens to close to the end of the reporting period.

It might be that we need to transfer allocated funds within the different categories (quite expensive transport costs of goods and living costs during the campaigns).

Unforeseen subcontracting (if applicable)

Not applicable

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Not applicable

Description of work carried out in T3.1 by beneficiary 26-BIRA

As part of the Task3.1, BIRA is responsible for the implementation and demonstration of the vertical profile retrieval of methane (CH_4) from the ground-based TCCON (Total Carbon Column Observing Network) measurements at few sites. The progress made during the current reporting period is discussed in this section.

Introduction

BIRA operates one TCCON site at Reunion Island since 2011.

In the framework of the H2020 RINGO project, we employ the SFIT4 algorithm to retrieve vertical profile of CH_4 from TCCON spectra (SFIT4TCCON) at six sites (Ny Ålesund, Sodankylä, Bialystok, Bremen, Orleans and Reunion Island) for measurements performed during the 2016–2017 time period. The TCCON spectra from all sites were transferred to BIRA by the site operators. The SFIT4 algorithm is based on the optimal estimation method (Rodgers, 2000) and is commonly used in the NDACC-IRWG community (Pougatchev et al., 1995). A Python tool is developed at BIRA to convert the TCCON spectra recorded in the OPUS format to the SFIT4 format. A DC correction is implemented in the Python tool to remove the noise caused by the solar intensity variation due to the presence of clouds during a scan.

Part 2. SFIT4TCCON retrieval strategy

Table 3. The retrieval parameters in the SFIT4 algorithm for the CH_4 vertical retrieval using TCCON spectra.

Retrieval window	5996.45 – 6007.55 cm^{-1}
A priori profile	WACCM climatology model mean of 1980 – 2020
Interfering species	CO_2, H_2O
Spectroscopy	ATM line list
Regularization method	Tikhonov
SNR	200
ILS	A linear polynomial fit of the extended linefit 14.5 output

The retrieval strategy for the CH_4 vertical profile has been investigated based on the TCCON spectra at Reunion Island. The retrieval window is the same as one of the three windows used in the GGG2014 and the ATM spectroscopy (G. Toon, 2014) is the same as used in the GGG2014. The a priori profiles for CH_4 and CO_2 are from the Whole Atmosphere Community Climate Model (WACCM) version 4 and they are fixed for all the retrievals. The a priori profiles of H_2O and temperature are from the NCEP re-analysis data with a 6-hour temporal resolution. The signal to noise (SNR) is set as 200 to generate the measurement covariance matrix. The instrument line shape (ILS) is set as a linear polynomial fitting and its parameters are simultaneously retrieved. The averaging kernel matrix (AVK) is the sensitivity of the retrieved CH_4 profile to the true one in the atmosphere. Our test at Reunion Island (see Figure 12) shows that the SFIT4TCCON CH_4 retrieved profile has a good sensitivity from the surface to the middle stratosphere (about 35 km). The total column averaging kernel show that the retrieved CH_4 total column has a good sensitivity in the whole

atmosphere, with a value close to 1.0 for all altitudes. In addition, the column averaging kernels slightly vary with solar zenith angle (SZA), which is more constant than the standard TCCON products. The degree of freedom (DOFs) for the signal of SFIT4TCCON retrieval is about 2.0–2.4, and this implies that the profile retrieval contains independent information in the troposphere and in the stratosphere.

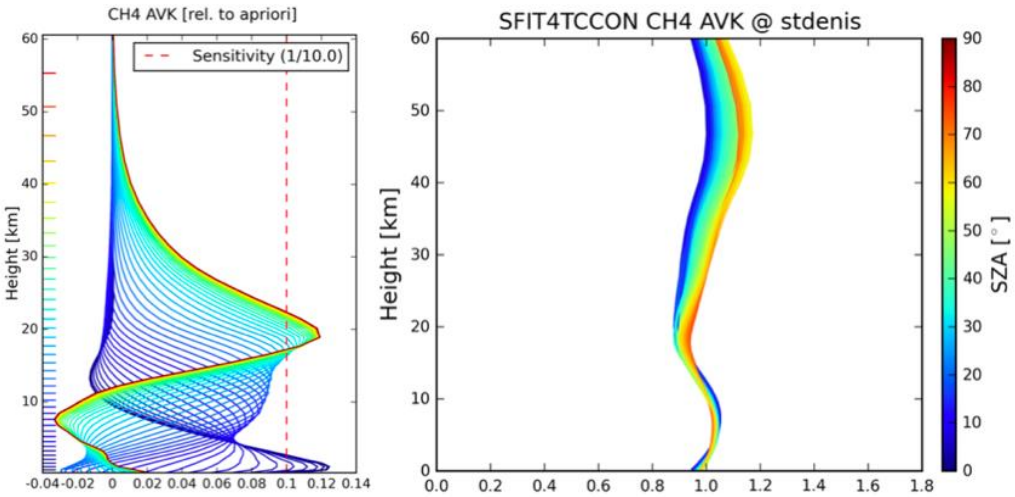

Figure 12. Left panel: a typical CH_4 averaging kernel matrix in relative unit [rel. to a priori] for the SFIT4TCCON retrieval at Reunion Island. Right panel: the CH_4 column averaging kernels for different solar zenith angles.

Comparison between SFIT4TCCON and TCCON XCH_4 measurements

TCCON XCH_4 products have been calibrated to the WMO scale and validated by Infrastructure for the Measurement of the Europe Carbon Cycle (IMECC) profiles over the European TCCON stations and HIAPER Pole-to-Pole Observations (HIPPO) profiles over the TCCON stations in Northern America, East Asia and Oceania. As the standard TCCON products have been calibrated to the WMO scale, we assume that there is no systematic uncertainty for TCCON XCH_4 products. The random uncertainty of TCCON XCH_4 products is about 0.5%. The XCH_4 values from the SFIT4TCCON retrievals at six sites in 2016–2017 are calculated and compared with the standard TCCON products. The systematic and random uncertainties of SFIT4TCCON CH_4 columns are about 3.0% and 1.0% respectively.

The XCH_4 from the SFIT4TCCON retrieval is calculated as

$$X_{CH4} = \frac{TC_{CH4}}{TC_{dryair}} = \frac{TC_{CH4}}{P_s/(gm_{dryair}) - TC_{H2O}(m_{H2O}/m_{dryair})}, \quad (1)$$

where TC_{CH4}, TC_{dryair} and TC_{H2O} are the total columns of CH_4, dry air and H_2O respectively; P_s is the surface pressure; g is the column-averaged gravitational acceleration; m_{H2O} and m_{dryair} are the molecular masses of H_2O and dry air, respectively; TC_{H2O} is from NCEP re-analysis data.

The mean and standard deviation of the XCH_4 difference between SFIT4TCCON and TCCON (SFIT4TCCON-TCCON) at the six sites are -2.3—2.5 ppb (-0.14—0.15%) and 4.7—9.9 ppb (0.3—0.6%) with the correlation coefficient of 0.76—0.93. The mean bias is relatively small compared to the systematic uncertainty of SFIT4TCCON retrievals, and the standard deviation is within the combined random uncertainty from SFIT4TCCON and TCCON retrievals. As an example, we show the difference between the SFIT4TCCON and TCCON standard XCH_4 retrievals at Orleans in Figure 13.

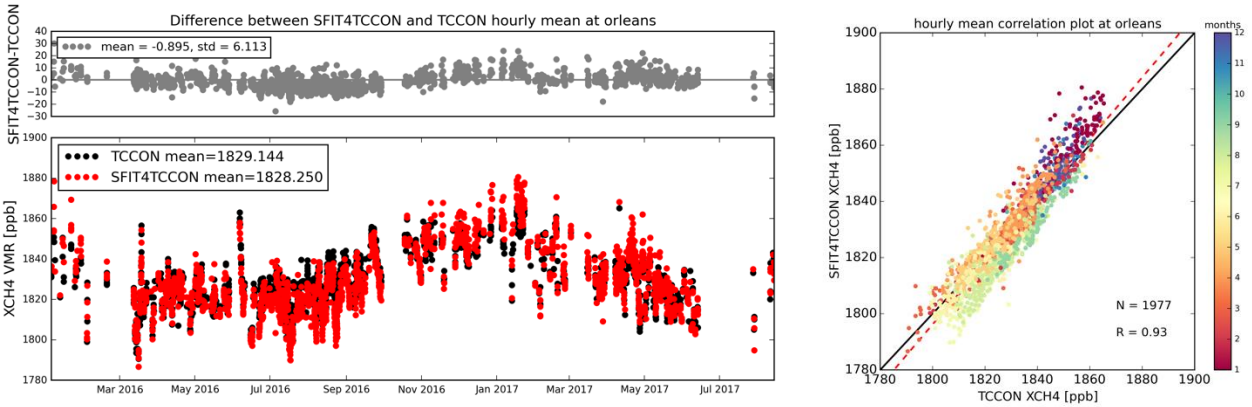

Figure 13. The time series of the hourly means and standard deviations from the SFIT4TCCON and TCCON XCH_4 measurements at Orleans, together with the absolute difference (unit: ppb) between them (left lower and top, respectively) and their correlation (right). The dots are coloured according to the measurement time (month) in the right panel.

Comparison between SFIT4TCCON tropospheric XCH_4 and surface in situ measurements

As the SFIT4TCCON retrieval has independent information in the troposphere and the stratosphere, the tropospheric XCH_4 from SFIT4TCCON retrievals are compared with the in situ measurements. The tropospheric XCH_4 is calculated following Eq.1, but using the partial columns of CH_4 and dry air in the troposphere. The tropopause height is derived from the NCEP re-analysis data.

To reduce the influence from the boundary layer, we compare the SFIT4TCCON tropospheric XCH_4 with tower measurements at 180 m at Orleans (see Figure 14). The tower measurements are generally larger than SFIT4TCCON tropospheric XCH_4, with few high peaks. The bias between SFIT4TCCON XCH_4 and tower measurements is about -32 ppb. The EDGAR emission inventory shows that the CH_4 emissions are quite high around Orleans which is mainly close to the surface. It is reasonable that the CH_4 concentration in the lower altitude measured by the tower in situ instrument is slightly higher than that of the high altitude retrieved from the FTIR measurements. The seasonal cycles of CH_4 from the in situ and SFIT4TCCON measurements are similar with the maximum in January – March and minimum in July – September. The peak-to-peak amplitudes from in situ and SFIT4TCCON measurements are also close (~ 60 ppb). The seasonal cycle of CH_4 in the troposphere is highly related to the OH seasonal variation, which is the major sink of CH_4 in the atmosphere.

Similar comparison is carried out at Reunion Island, where the TCCON site is located at Saint Denis (85 m above sea level) and the surface in situ measurements are operated at Maido (2155 m above sea level), about 20 km away from Saint Denis. Figure 14 shows that the in situ measurements are generally weaker than the SFIT4TCCON XCH_4, the bias between SFIT4TCCON XCH_4 and in situ measurements is about 23 ppb. Zhou et al. (2018) used the FLEXPART backward trajectories to show that the air near the surface above Reunion Island is mainly coming from the Indian Ocean and partly from Southern Africa, and the air mass in the middle and upper troposphere is mainly coming from Africa and South America. As CH_4 emission on the land is much larger than that from the ocean, it leads to the fact that SFIT4TCCON XCH_4 is systematically larger than the in situ CH_4 at the surface. The seasonal cycles of CH_4 from the in situ and SFIT4TCCON measurements at Reunion Island are similar with the maximum in August - October and minimum in January - March. The peak-to-peak amplitudes from in situ and SFIT4TCCON measurements are also close (~ 60 ppb).

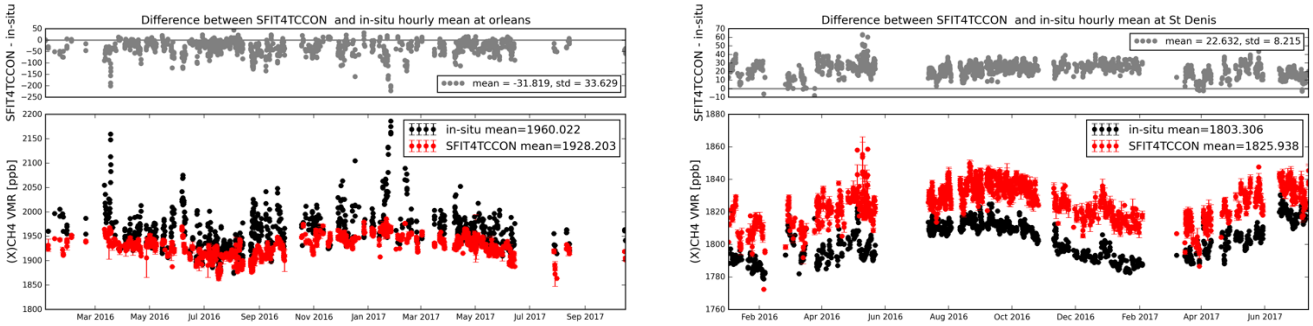

Figure 14 The time series of the hourly means and standard deviations from the SFIT4TCCON tropospheric XCH_4 and tower CH_4 measurements on 180 m at Orleans (left panels) or surface CH_4 measurements on Maido mountain (2155 m) at Reunion Island (right panels), together with the absolute difference (unit: ppb) between them (lower and top, respectively).

Comparison between SFIT4TCCON and TCCON tropospheric and stratospheric XCH_4 measurements

Previous studies of Wang et al. (2014) and Saad et al. (2014) have shown that one can also derive the tropospheric and stratospheric XCH_4 from the TCCON spectra based on the known relationships between hydrogen fluoride (HF) or nitrous oxide (N_2O) (which are also TCCON standard products) and CH_4 in the stratosphere. In this section, the tropospheric and stratospheric XCH_4 from SFIT4TCCON are compared with the N_2O and HF proxy method (see Figure 15). Overall, the tropospheric and stratospheric XCH_4 from the N_2O and HF proxy method are very similar but show a systematic bias. As the TCCON XHF has not been validated by aircraft measurements, the systematic bias probably comes from the uncertainty of the TCCON XHF product. The variations of the tropospheric and stratospheric XCH_4 from the proxy method are much weaker than those from the SFIT4TCCON retrievals, because the proxy method assumes that the HF or N_2O concentration are constant in the troposphere. According to the comparison between the SFIT4TCCON tropospheric XCH_4 with tower or mountain in situ measurements (see Part 4), the amplitude of the seasonal cycle of tropospheric and stratospheric XCH_4 from the proxy method seem to be too low. TCCON HF retrievals are strongly affected by water vapour, therefore the proxy method using HF is not valid for moist sites, e.g. Reunion Island. The seasonal cycles of the tropospheric or stratospheric XCH_4 from the SFIT4TCCON retrievals and the proxy method are similar. However, apart from Reunion Island, the tropospheric XCH_4 from SFIT4TCCON retrievals are systematically lower than that from the proxy method.

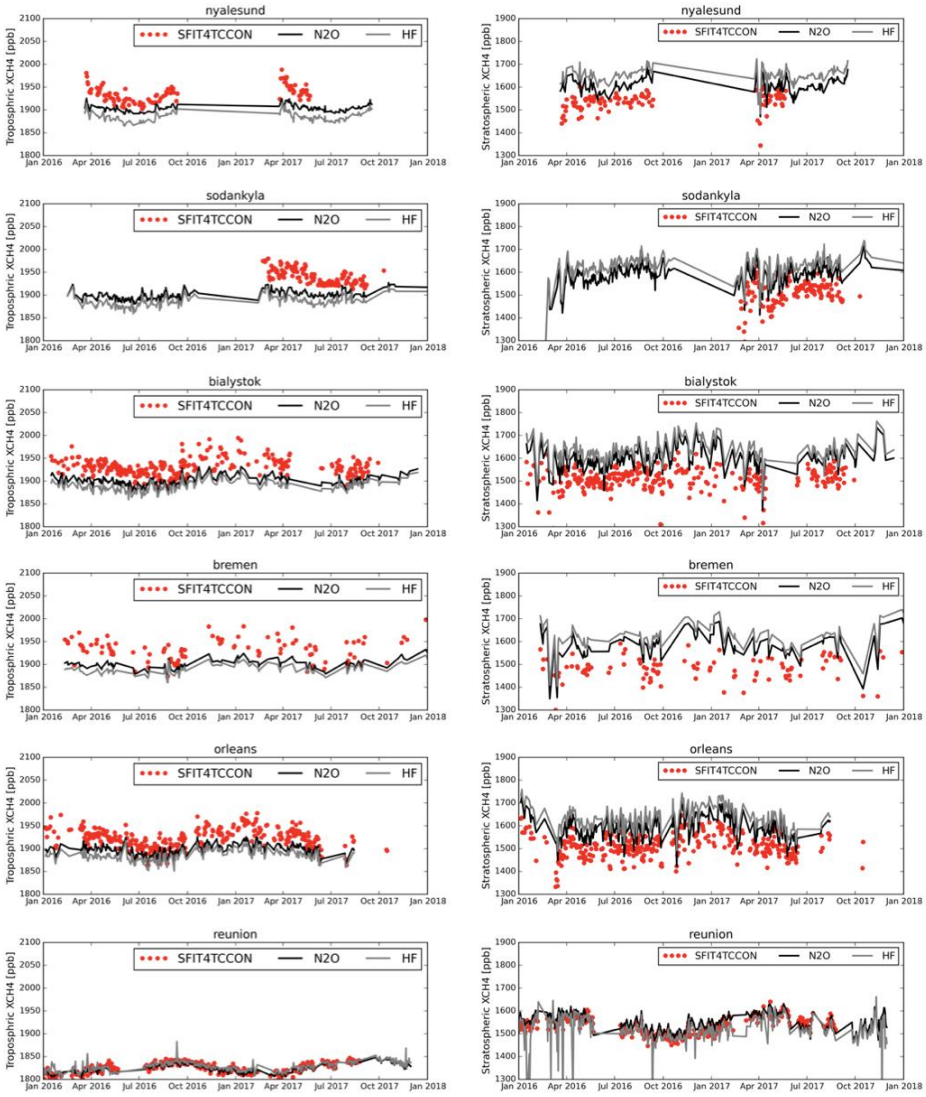

Figure 15 The time series of the tropospheric (left panels) and stratospheric (right panels) XCH_4 from SFIT4TCCON and the N_2O and HF proxy method at six TCCON sites.

Comparing tropospheric and stratospheric XCH_4 from SFIT4TCCON retrievals with AirCore measurements at Sodankylä

The time series of the XCH_4 from SFIT4TCCON and AirCore measurements in the troposphere, stratosphere and the whole atmosphere, together with their relationship are shown in Figure 16. It is confirmed by the AirCore measurements that there are almost no systematic biases (a=0.999) for the SFIT4TCCON XCH_4 measurements. However, the SFIT4TCCON tropospheric XCH_4 are 1.2% larger than the AirCore measurements and the N_2O method tropospheric XCH_4 are 0.5% lower than the AirCore measurements. The SFIT4TCCON stratospheric XCH_4 are 4.1% lower than the AirCore measurements and the N_2O method tropospheric XCH_4 are 2.2% larger than the AirCore measurements. We suspect that the systematic bias of the SFIT4TCCON partial column is mainly from the uncertainty of the spectroscopy. Further investigation is needed in the future. The proxy method has its limitations as it assumes that the CH_4 concentration in the upper troposphere is the tropospheric XCH_4, which also leads to systematic biases of the stratospheric and tropospheric XCH_4.

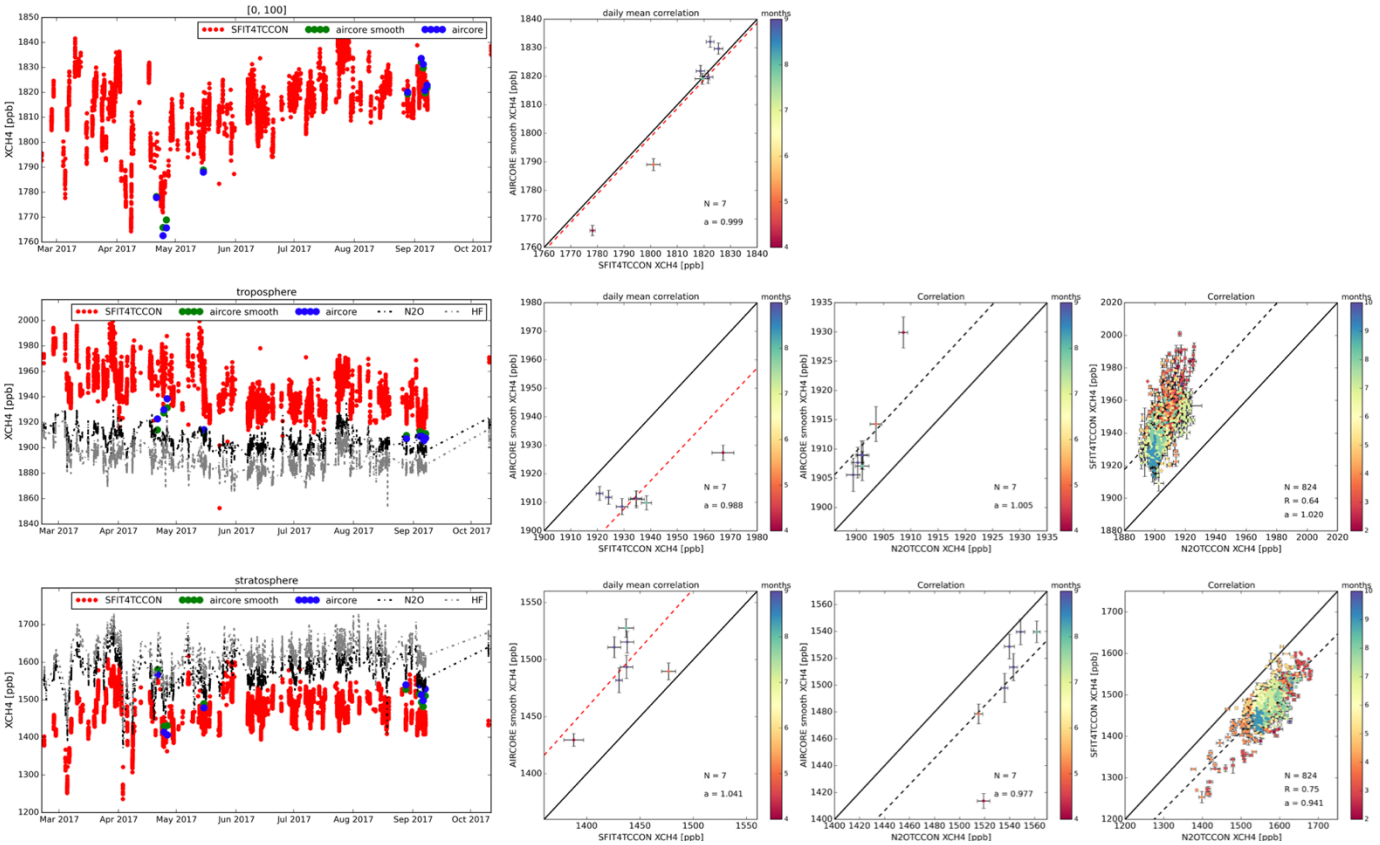

Figure 16. The time series of the XCH_4 from SFIT4TCCON and AirCore measurements in the whole atmosphere (top), in the troposphere (middle) and in the stratosphere (bottom) for the measurements performed in 2017, together with the scatter plot between them on the right. The time series of the proxy method (both HF and N_2O) are also shown for the tropospheric and stratospheric XCH_4, together with the scatter plots between the results from the N_2O proxy method and the AirCore measurements or the SFIT4TCCON measurements. In the scatter plot, the data are linearly fitted ($y = ax$). Note that the AirCore measurements are smoothed using the FTIR retrievals, when comparing the co-located data pairs.

Outlook and next steps

The tower in situ measurements at Bialystok will be compared to the SFIT4TCCON measurements, as they become available. Thanks to the ESA funded FRM4GHG and EU-H2020 funded RINGO projects, more AirCores will be launched in 2018 year at Sodankylä. The vertical profiles from the AirCores will be used to validate and calibrate the FTIR measurements. For the SFIT4TCCON retrieval strategy, we now used the standard TCCON retrieval window. As there are systematic uncertainties for the tropospheric and stratospheric XCH_4 measurements from SFIT4TCCON retrievals, we will test different retrieval windows and different spectroscopies. If we cannot find a perfect window to reduce the systematic bias of the tropospheric and stratospheric XCH_4, scaling factors will be applied to the SFIT4TCCON tropospheric and stratospheric XCH_4 products based on the AirCore measurements.

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Zhou, M., Langerock, B., Vigouroux, C., Sha, M. K., Ramonet, M., Delmotte, M., Mahieu, E., Bader, W., Hermans, C., Kumps, N., Metzger, J.-M., Duflot, V., Wang, Z., Palm, M., and De Mazière, M.: Atmospheric CO and CH4 time series and seasonal variations on Reunion Island from ground-based in situ and FTIR (NDACC and TCCON) measurements, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-218, in review, 2018.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
BIRA is not directly part of the vertical profile measurements performed by AirCore as the MS12. We will use the AirCore measurements as and when available to compare with our tropospheric and stratospheric retrieved columns.
Deviations from the implementation of task
Bialystok measurements has not been started yet.
Deviations from the planned use of resources
There were no deviations from the DoA within task 3.1
Unforeseen subcontracting (if applicable)
N/A
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

Task 3.2: Improving atmosphere measurements on voluntary observing ships

Task leader: 27-IOW
Beneficiaries involved in T 3.2: 1-ICOS ERIC, 4-UVSQ, 5-UHEI_MPI-BGC 23-GEOMAR

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
None in the reporting period					

Description of work carried out in T3.2 - Overview
The ICOS Ocean observational program is running autonomous systems to measure the partial pressure of CO_2 in surface waters on commercial carrier ships (Voluntary Observing Ship, VOS) which allows for high spatiotemporal data coverage, and is a major component of the OTC data stream. Atmospheric dry air mole fractions are measured less frequently or not on VOS lines, and are usually not acquired according to standards required for high-quality atmospheric measurements. Improving the atmospheric part of the measurements on VOS lines according to the WMO and ICOS guidelines has been identified as a potential

cost-efficient way to enhance the atmospheric data coverage and to gather data from areas difficult to access, in some cases at critical regions in terms of air mass boundaries. Task 3.2 will develop and test technological solutions for three different settings and approaches, and assess the added value for the atmospheric observation network. These include the Baltic VOS line between Lübeck and Helsinki (IOW), the transatlantic line (GEOMAR) and the Colibri line from France to French Guinea (UVSQ). ICOS CAL (UHEI_MPI-BGC) will provide standard gases and be involved in flask sampling analysis for quality insurance, UVSQ will implement the platforms into the ATC data stream. Modelling efforts will be used both for quality control and evaluation of the added value of this kind of data for the scientific use, e.g. inverse modelling applications.
The original work plan foresaw that all 3 lines were operational by month 18, with Deliverable 3.2 and Milestone 29 on reporting the implementation and technical realization due in Month 20 of the project. Due to very different issues with the carrier ships, a request for postponement of the deliverable and milestone is foreseeable, despite the fact that all partners have been quite active and the defined interim goals have been met (see individual descriptions of the beneficiaries). However, we do not foresee the overall fulfillment of Deliverables 3.2 and 3.3 at risk within the time frame of the project.

Description of work carried out in T3.2 by Beneficiary 5 -UHEI_MPI-BGC

Linked Third Party MPI-BGC (to beneficiary 5 UHEI) finalized the preparation and calibration of the reference gases to be used for the calibration and quality control of the VOS measurement systems for atmospheric CO_2 and CH_4 measurements operated by the partner participants in Task 3.2. The production of the respective standard gas sets has been completed and the partners have been provided with these sets.
If more detail is needed, we could add that each of the sets was provided with four 20 L high pressure cylinders: three calibration gases with targeted composition of approximately 380 / 410 / 450 ppm CO_2; 1800 / 1950 / 2100 ppb CH_4; 320 / 330 / 340 ppb N_2O; 80 / 150 / 240 ppb CO and one target gas for quality control purposes. All gases have been calibrated according to the current WMO scales.

Description of work carried out in T3.2 by beneficiary 27-IOW

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. Though the first Deliverable and Milestone is not within the first reporting period (i.e. month 20), work toward the implementation of the system was meant to start immediately after the ramp-up phase (months 1–6).

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
Deviations from the implementation of task
Beneficiary 27-IOW started with unforeseen delay into the project, as it turned out that the originally envisaged status as linked partner to partner 23 could not be realized due to unresolved legal issues. Therefore, IOW became full beneficiary as part of the amendment as of August 2017, and at the same time was assigned Task Lead of Task 3.2.
Planning of work towards Deliverable 3.2 (Baltic Sea) started immediately, but progress was slowed by two further unforeseen circumstances:

(a) The purchase of the instrument to be used on the Baltic line (by partner 1 – ICOS ERIC) was delayed due to issues between the supplier and ICOS, as well as custom declarations etc. At the end, the sensor, which is the key component of the planned instrumentation, did not arrive at IOW before February 2017, i.e. month 14 of the project.
(b) Despite earlier request, communication and positive feedback from the ship's owner, additional instrumentation was finally not granted on VOS Finnmaid, despite the fact that the already installed seawater trace gas system has been maintained for 15 years now, with excellent relations to the ship's crew. The reason has to be seen in new rules regarding the presence of personnel not hired

by the company on the upper deck of the ship, and to space requirements due to new required installation.

As the ship's surrounding might affect the structural design of the component's assembly, the instrument development did not proceed as envisaged and the work progress is behind schedule. Still, strong efforts have been and are being made towards the implementation on a suitable carrier in the Baltic Sea. The actions are summarized as follows:

- Need and requirements for the calibration gases have been discussed with the partners and ICOS CAL (UHEI). The calibration gases are at IOW now.
- Through discussions with members of the ATC, the design of the system has been finalized and most parts have been recently ordered. Using the ICOS network proved tremendously helpful for the design and ATC-specific recommendations.
- Potential options for autarkic data transfer from/to the ship have been identified by IOWs marine instrumentation group.
- Alternatives for a suitable ship of operation have been sought and identified. Through the network of the Alg@line and BONUS INTEGRAL networks, contact was made to the ship's owner of VOS Tavastland, commuting between Helsinki and Umeå on a weekly basis. The ship is instrumented with a GO-type pCO_2 system by SMHI, and would be the ideal platform for the planned atmospheric work. The instrumentation on Tavastland is currently discussed as additional ICOS Ocean component from Sweden. Negotiations look promising, but are not finalized yet.

So, despite the delay, it is envisaged that the goals within Task 3.2 can be met without losses.

Deviations from the planned use of resources

Due to the reasons above, the purchase of components for the peripherals of the system has been delayed with most of the procurements to be paid in the 2nd reporting period. Use of personnel is slightly behind the original plan due to the same reasons. This situation will be corrected over the next reporting period.

Unforeseen subcontracting (if applicable)

No unforeseen subcontracting

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

No unforeseen use of in kind contribution from third party

Description of work carried out in T3.2 by beneficiary 1-ICOS ERIC

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. ICOS ERIC decided on the sensor to be used, procured the sensor, and arranged for testing of the sensor at the ATC and further delivery to partner IOW. Partner IOW will use the sensor to fulfil their obligations in Task 3.2, while the sensor remains in the possession of ICOS-ERIC.

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

Procurement, due to general considerations in the relation between the instrument supplier PICARRO and ICOS-ERIC, took longer than expected. Also, some difficulties in connection to customs and transport caused further delay. The sensor was finally delivered to partner IOW in month 14 of the project.

Deviations from the implementation of task

While ICOS-ERIC fulfilled their duties within Task 3.2., the delay in sensor procurement, together with other issues, affected the work plan of partner IOW (see below).

Deviations from the planned use of resources

None

Unforeseen subcontracting (if applicable)
None
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
None

Description of work carried out in T3.2 by beneficiary 4-UVSQ
Our work on task 3.2 can be split into two distinct parts: one dedicated to the instrumental system definition, setup and testing, and the second one focusing on the data processing of atmospheric measurements from the three ships involved in this task.
We have identified a commercial vessel named Colibri to host our equipment. This vessel already hosts scientific equipment dedicated to pCO_2 measurement in the seawater, a complementary and interesting data to be used with our future measurements of atmospheric CO_2. This boat is regularly crossing the Atlantic Ocean between France and French Guiana. A visit of the ship has been done in March 2017 confirming the possibility of installing our equipment in the vessel and contacts have been taken to initiate a partnership between the company and LSCE.
In parallel to this work, a dedicated experimental set up has been developed and tested to enable CO_2 atmospheric measurements onboard a commercial ship. Our system is composed of the following elements:

- A greenhouse gases analyzer (CO_2, CH_4, CO, H_2O cavity ring down spectroscopy analyzer, Picarro G2401);
- A set of calibration and quality control compressed air cylinders (4) provided by the central calibration centre of ICOS-RI (Integrated Carbon Observation System Research Infrastructure) connected to a multi-position valve enabling the sequential measurement of the different cylinders and atmospheric air;
- A GPS set up to recover real time positioning of the vessel;
- A back-up system to ensure the data safeguard;
- An uninterruptible power supply to preserve the equipment in case of power shut-down.

Most of these elements are integrated in a single compact rack (except the cylinders) that can be easily deployed aboard the vessel. A dedicated inlet will be placed on the upper floor of the boat, away from the main exhaust of the vessel and connected to the multi position valve through Dekabon tubing. Complementary meteorological data will be provided independently by meteorological sensors already installed on the vessel and processed by Meteo France.
This instrumental setup has been first mounted and tested at LSCE and was then installed and used aboard the Kommandor Iona vessel during the intensive scientific campaign AQABA across the Mediterranean and around the Arabian Peninsula. This setup has shown to be reliable and adapted. It provided CO_2, CH_4 and CO data all along this campaign that are currently under interpretation by a Master student.
Those data have been processed by the ICOS atmospheric database which has performed the technical developments to process mobile instruments. The processing of G2401 Picarro data onboard ships is operational in the ICOS database. As a demonstration, the data obtained during the AQABA campaign in summer 2017, using the analyzer which will be deployed onboard COLIBRI for RINGO, have been successfully processed. The processing of the GPS data and metadata is under development (70 % of implementation done).

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
Deviations from the implementation of task
Due to difficulties to elaborate a final partnership agreement between LSCE authorities and the Compagnie Maritime Nantaise who is the owner of the Colibri ship, the equipment has not yet been installed aboard. The main problem lies in the insurance policies where a common agreement has to be found between both parties. There have been several interactions between both partners which took quite some time but the

latest news is constructive and we hope to be able to solve this last critical point beginning of autumn and then to install and run our equipment by the end of this year (depending on the opportunity given by the vessel staying on harbor).

Deviations from the planned use of resources

Due to the above-mentioned reasons, the actual use of resources of other direct costs is below the planned use of resources. In order to correct this situation, we may file a request for a transfer of cost categories from direct costs to personnel costs during the next reporting period.

However, concerning personnel costs, the actual use of resources is in line with the planned use of resources.

Unforeseen subcontracting (if applicable)

No unforeseen subcontracting

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

No unforeseen use of in kind contribution from third party

Description of work carried out in T3.2 by beneficiary 5-UHEIMPI-BGC

Beneficiary 5-UHEIMPI-BGC finalized the preparation and calibration of the reference gases to be used for the calibration and quality control of the VOS measurement systems for atmospheric CO_2 and CH_4 measurements operated by the partner participants in Task 3.2. The production of the respective standard gas sets has been completed and the partners have been provided with these sets.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the DoA

Deviations from the planned use of resources

No deviations from the DoA

Unforeseen subcontracting (if applicable)

N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Description of work carried out in T3.2 by beneficiary 23-GEOMAR

The role of GEOMAR was to improve the atmospheric measurements with an existing installation for seawater pCO_2 measurements onboard the transatlantic VOS. This VOS line was established in 2005 onboard the commercial vessel M/V Atlantic Companion which crosses the North Atlantic between UK and Canada twice during its 5-week roundtrip. The ship also served various European ports (Antwerp, Hamburg, Gothenburg) so that the European shelf was well covered. 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. Since the Atlantic Companion went out of service in 2014, the installation moved to the sister ship M/V Atlantic Cartier which serves on the same route. In April 2017, the first tests were conducted on board in order to improve the precision of atmospheric CO_2 measurements. We installed 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 no significant effect on the measurements.

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

Deviations from the implementation of task

The VOS line M/V Atlantic Cartier went out of service in summer 2017 and all equipment had to be removed from board. We were promised by the ship's owner that we would be able to move to the replacement ship M/V Atlantic Sail in 2017. Due to enormous problems with this new built ship, we couldn't start the installation on board the M/V Atlantic Sail before June 2018. The installation is nearly finished and we plan to start the measurements in August 2018. This will delay our tasks within RINGO but will not hinder us from fulfilling our tasks within the project time.

Deviations from the planned use of resources

There are no deviations from the planned use of resources.

Unforeseen subcontracting (if applicable)

No subcontracting.

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/A

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: NERC/UoE (8)

No Deliverables due in the reporting period.

List of milestones due to be completed within this task within this reporting period: none

Description of work carried out in T3.3 by beneficiary 8-NERC_UoE

Major uncertainties in marine and freshwater CO_2 uptake/release occur because of the sparseness of observations, especially in locations remote from shipping routes or from laboratories where marine observations are made. Such locations include large ocean regions such as the Arctic and Southern Oceans, but also most rivers, estuaries and large lakes, and some near-shore coastal ocean environments which are not crossed by major shipping routes.

ICOS can address this deficiency using instrumentation mounted on autonomous surface vehicles (ASVs). ASVs are a rapidly developing technology, such that there are now a number of designs commercially available. Instruments that will work on such vehicles must fulfil a number of stringent requirements: they need to be compact, robust, to be able to survive storm and capsizing, retain their accuracy over extended periods and have low power consumption. The accurate quantification of air-water CO_2 fluxes, especially in open oceanic conditions, requires a high-precision measurement of surface pCO_2, and for ICOS observations to maintain class 1 status, regular calibration of the measurements with gas mixtures traceable to WMO standards is needed. No such ASV-mountable instrument meeting all these criteria currently exists.

The University of Exeter has designed and commenced development of such an instrument specifically for ICOS, to fulfil these criteria. Our design will make both in-water and atmospheric CO_2 measurements, and includes a regular calibration cycle with standard gases held in miniature high-pressure cylinders on board the vehicle.

Since the start of the project in January 2017 up until June 2017 we focused on the command and control of the instrument, specifically and several off the shelf, single board computers, including Raspberry Pie or Beagle Bone. These were coupled with third party capes. The system became a single board computer (SBC) stacked with a relay cape to drive the manifold, an input/output cape to drive the sensors and an RS232 cape to interface with a detector.

During the months of June 2017 to December 2017 we then focused on air handling, constructing prototype, manifolds, equilibrators and air blocks.

During the months of December 2017 through to June 2018 we spent time bringing all four modules together into a single case in preparation of ASV integration.

The Instrument is made of four modules:
Detector: The LI-840A is an absolute, non-dispersive infrared (NDIR) gas analyser based upon a single path, dual wavelength infrared detection system. It is heated for stability and has a water channel, pressure and temperature for real time corrections of CO_2 concentrations. Power consumption is less than 4W.

Manifold and Pump: Twelve latching micro valves fitted to a generic manifold handle the gas flow between modules. Being latching and very small allow for low system power and volume. The system is plumbed with a combination of Tygon and 1/16 stainless steel tube. The diaphragm pump is a KNF NMP09 operating at 5V.

Electronics: Have been developed at NOC using an in-house single board computer for onboard logging of data with a custom-made input/output board allowing the interfacing of modules.

Consumables: This is in two parts. Three microcan 200 bar cylinders holding calibrated air with CO_2 concentrations of 200, 300 and 400 ppm. A regulator reduces the flow to 0.5 bar. Each cylinder holds 40 L of gas. The second part is a gas dryer made of a coil of Nafion tubing encased in Drierite desiccant.

The external parts of the instrument are:
Equilibrator: A simple H shaped, low volume equilibrator, designed and built in house, is used. Air is bubbled in, creating a flow through the H. The sample is taken from the top of the head space. The head space temperature and pressure are measured and rapid equilibration times have been achieved in the laboratory. Currently made in acrylic, the material may change to protect against bio-fouling.

Air block: Atmospheric air is sampled from the mast to the detector via a waterproof membrane. The equilibrated air is also passed up the mast, through a membrane and onto the instrument. This protects the instrument from flooding. The final component is a vent.

Metrological package: An AirMar WX200 gathers metrological data via RS232. Windspeed, direction, temperature, barometric pressure, GPS coordinates and heading are all recorded. This is mounted at the top of the mast and waterproof to IPX7.

Vehicle integration: As the instrument is self-contained in a peli style case, it only requires a 12V power supply to operate. The Air block and Met components are mounted on a mast and have 5 connections: Air in, Air out, Eq in, Eq out and Met RS232. The equilibrator has 3 connections: Eq in, Eq out and a sensors cable and is mounted to the hull on a slider allowing for a constant water height regardless of the vehicles attitude.
The main capability of the device is for the autonomous registration of pCO_2 levels in sea water and air. A summary of the development of important components of the instrument is detailed below.
CO_2 Sensor: LiCor 840 and GasCard sensors have been tested and proven to be compatible with assumed specification of final build. Integrated temperature and pressure sensors (and H_2O level in case of LiCor) enable accurate measurements of xCO_2 levels in gas sample.
Meanwhile development of dedicated sensor is advancing. The objective is to reduce power consumption, yet keep accuracy. The current design includes a miniaturised cell with integrated diode, two IR sensors (H_2O and CO_2) and two thermistors.

Auxiliary sensors: External thermistors, flow meter, pressure and humidity sensors were tested. Upon integration with boards, connection between those items was confirmed one by one. For each type of sensors calibration protocol was established and sensitivity was assessed one at a time. Precision is within satisfactory range. All sensors were successfully integrated in functioning build and further tests of all items at once are waiting to be performed (with special interest in pressure sensor).
Electronic boards: The electronic boards were tested to communicate correctly with all auxiliary sensors, valves and pumps. They log data and communicate with PC software correctly.
Consumables (gas and drier): The low internal volume drier design (based on standard drierite drier) was thoroughly tested. Performance is satisfactory – air at outlet is being significantly depleted of water vapour compared to air at inlet, meaning that the system will be protected from condensation. However, drying in this way will never be complete (some humidity will remain in sample) or stable (humidity will increase as drierite accumulates more water). Therefore, numerical drying will be needed to perform pCO_2 calculations. More driers can be connected in series (subject to space availability) to enhance performance and prolong service time.
Three gas standards with CO_2 levels bracketing assumed concentration in sample were tested. Three small cylinders were successfully integrated into system and operated from within small transport case. An issue has been noticed that is going to be addressed shortly, namely control over outlet pressure. Current equipment consists of pressure reducer with very broad scale (minimum difference between ticks is 500 mbar) compared to system requirements (overpressure in LiCor should not be more than 150 mbar). This leads to high flow rates (calibration gases are consumed too quickly) and inaccuracies (and sensor is sensitive to pressure, so sample pressure should be similar to calibration pressure). This issue is approached from two angles: i) incorporation of flow controller into system, ii) sourcing high-spec reducer that would fit better into requirements.
Equilibrator: Various laboratory-grade builds were tested, by replacing the RS pump with KNF, one enabled higher pressure during equilibration. Therefore, water column can be higher and/or sparger can be introduced. Both changes decrease equilibration time significantly. Next iteration will be sturdier construction ready for field tests.
Manifold and valves: Switching in the system was realised by latching micro valves in order to minimise dead space (and therefore operating times) and power consumption. Initial experiments suggest that those elements are too restrictive resulting in low flow rate. Therefore, we have switched to valves with decreased restrictivity by Lee Co. Those items proved to be more suitable for our purposes.
Our current build uses off-the-shelf 8-valves manifold with ports meant for 1/8’ flexible tubing. It was tested and proved to work.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
The instrument is delayed in lab tests whilst we correct an issue with pressure and flow rates. We are working to resolve these issues at present and aim to, once corrected, integrate the instrument into an ASV during the summer months.
Deviations from the implementation of task
None
Deviations from the planned use of resources
None
Unforeseen subcontracting (if applicable)
N/A
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/A

Task 3.4 Making non-CO2 - GHG eddy covariance measurements operational

Task leader: 9-UHEL
Beneficiaries involved in T 3.4: 3-UNITUS, 28 DWD, 11-ETH; 8-NERC, 22-DTU

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
MS23	Common data set for non-CO_2 eddy covariance measurements compiled from existing sites	WP3	9-UHEL	18	Common data set for non- CO_2 eddy covariance measurements compiled from existing sites

Description of work carried out in T3.4 by beneficiary 9-UHEL

Beneficiary 9-UHEL contributed to Milestone MS23 by collecting a list of ten flux tower stations where CH_4 and N_2O flux datasets are available. There are 8 stations from Europe and 2 from the United States. The data being collecting includes metadata, raw data and 30 min flux data. The activity is done in collaboration with the partners 3-UNITUS (hosting the European database and the ICOS ETC) and 11-ETHZ.
We have established a collaboration with Sara Knox (Stanford 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.
We have hired a PhD student to work within this task, in particular investigating the usage of different spectral correction approaches on CH_4 and N_2O fluxes and their impact on annual budgets. Data from some of the above-mentioned stations are used.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.4 by beneficiary 3-UNITUS:

There were no deliverables in the period where UNITUS contributed. A Postdoc has been hired to contribute to the discussion on the processing of CH_4 and N_2O fluxes and to work on the implementation of the results in the ICOS ETC pipeline. Started to work on the analysis of the processing steps involved. As soon as the data will be available, the evaluation of the different options will start.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.4 by beneficiary 28 DWD

Beneficiary 28 DWD contributed to Milestone MS23 by re-post-processing the CH_4 dataset of Skjern, DK, performing a flux driver analysis for different time steps and seasons, testing gap filling techniques for CH_4, and finally participating to the Fluxnet CH_4 workshop in Washington.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.4 by beneficiary 11-ETHZ:

In a first step, 11-ETHZ (Grassland Sciences group: Prof. Nina Buchmann, group leader; Lukas Hörtnagl, data scientist) set up a dedicated server that accepts N_2O and CH_4 flux data from RINGO contributors. The server aims to collect currently available eddy covariance (EC) non-CO_2 flux data for dissemination among T3.4 partners. The collected data constitutes the basis for the following analyses and developments.
Based on this data, 11-ETHZ investigates flux gap-filling and u_* filtering for non-CO_2 fluxes. To this end, 11-ETHZ is currently developing (in progress) a novel Python-based, open source flux analyser tool, comprising a graphical user interface (GUI) that visualizes and analyzes the impact of selected gap-filling and u_* filtering settings on ecosystem fluxes in real-time. The tool consists of multiple time series processing modules that can be directly applied to measured EC fluxes using the GUI. Currently, the tool is in pre-alpha stage with the following basic functionality already implemented: plotting, statistical analyses, resampling and default gap-filling methods that are commonly used for CO_2 fluxes. Additional gap-filling algorithms (e.g. machine learning, Bayesian) are currently tested and will be added to the tool in the near future. Kritika Grover (Indian Institute for Technology, Delhi, India) contributed to this task by investigating the impact of machine learning algorithms on annual non-CO_2 greenhouse gas budgets of managed grasslands in an internship. The tool will also include detailed u_* filtering analyses that will allow to investigate the impact of the filtering in

combination with selected gap-filling approaches to facilitate the calculation of annual N_2O and CH_4 budget uncertainties. The ultimate aim of this tool is to improve post-processing of non-CO_2 fluxes and to facilitate their accurate quantification on different timescales. The Python modules of this tool will be published (free and open source) in combination with the GUI, but also separately as stand-alone scripts for easy implementation in already existing programming code of other research groups.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.4 by beneficiary 8-NERC:

NERC led the finalization of a first protocol on non-CO_2 GHG (i.e. CH_4 & N_2O) eddy-covariance flux measurements which is currently undergoing review for publication in *International Agrophysics*. This sets out the first international standard for making such measurements across networks and highlights uncertainties and research needs. This paper highlights, amongst other issues, the difficulty of processing fluxes close to the detection limit. This is a regular problem for N_2O, the fluxes of which can be highly episodic and small for extended periods.
To address this issue and following the recommendations of the protocol, NERC has designed an overflow inlet for the automated periodic experimental quantification of time-lag, response time and analyzer noise and this has been implemented on a CO_2/N_2O flux system at one of NERC (CEH's) long-term ecosystem monitoring sites for testing. Automated data analysis routines have been developed to evaluate these measurements. This work will evaluate whether this experimental approach should be rolled out as a standard measure across the ICOS network and it will optimize the data handling protocol to be implemented in the ICOS eddy-covariance processing routines.
There were no deliverables or milestones associated with this work during the reporting period.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.4 by beneficiary 22-DTU:

Beneficiary 22-DTU contributed to the task by establishing a sub-task on spectral correction strategies that were seen especially important for non-CO_2 GHG flux measurements. The eddy covariance technique relies on accurately measured time series of vertical wind speeds and the concentration of the measured gas, here N_2O or CH_4. However, sensor imperfections lead to dampening of high frequencies, which would lead to underestimation of the fluxes if not corrected for. These corrections are generally based on spectral analysis. For CO_2, ICOS has agreed upon using power spectra. For non-CO_2 GHG, this method might be problematic, as the large signal-to-noise ratio affects power-spectra more than co-spectra. A systematic approach was developed and illustrated with corrections of N_2O flux data obtained at the Easterbush campaign, where the InGOS project established an intercomparison of eddy covariance N_2O flux systems. The two approaches, correction based on power spectra vs. correction based on co-spectra, were programmed and presented on the GA (March 2018). As a contribution to achieve Milestone MS23, the usefulness of the InGOS Easterbush database for demonstration and analysis was shown.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

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

Task leader: 3-UNITUS_INRA
Beneficiaries involved in T 3.5: 12-UAnt

Description of work carried out in T3.5 by beneficiary 3-UNITUS_INRA:

The task will focus 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 will identify the main improvements needed in terms of geographical and climatic coverages. It will also assess measurement 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 are identified within this task and summarized as:
Phase A. Metrological performances of the Ecosystem network.
Phase B. Attribution.
Phase C. Roadmap.
This short report presents the main objectives that have been discussed and defined for this task as well as the first exploratory work. It is organised in 6 sub-sections.

1. Context reminder and main objectives description.

This task aims at enabling the Ecosystem network of ICOS RI to play a pivotal role for the detection, quantification and attribution of the impacts of the main environmental and anthropogenic drivers on the temporal and spatial changes in ecosystem atmosphere GHG exchanges.
From an analysis of the available temporal series of GHG measurements across Europe, we shall establish the optimal design of the ICOS ecosystem network for detecting and attributing the temporal changes in GHG balances to its respective drivers.
The main questions are:

- ⇨ What are the performances of the ICOS Ecosystem stations network, in terms of accuracy, precision and time consistency? Behind this comes immediately the question of which variables are the most relevant for detecting environmental impacts on European continental ecosystems and their atmospheric exchanges, e.g., Net Ecosystem Exchange (NEE) and its partitioned components: ecosystem Respiration (Reco) and Gross Primary Production (GPP), energy balance components, phenological variables?
- ⇨ What would be the impacts of the upcoming changes in GHG potential drivers (climate, pollutions, practices) for the next 30 years (2020–2050) on the variables as measured by the ICOS Ecosystem network?
- ⇨ Considering these two questions: How to enhance the ICOS Ecosystem network performances, in terms of coverage, inter-operability, and completeness? What are the main priorities and how can they be implemented along a coordinated roadmap with companion infrastructures?

It came out that we need to know what the uncertainties in fluxes measurements are, both with the network as it existed historically and as it is expected to be improved within ICOS recommendations, especially as regards the carbon dioxide fluxes: i.e NEE, Reco & GPP, when using eddy-covariance technology.
Drivers of these GHG fluxes that we have been focusing on in this study are physical variables (temperature (T), relative humidity (RH), soil water content (SWC), air water vapor pressure saturation deficit (VPD), precipitation (P), radiations (SW_{in}, SW_{out}, LW_{in}, LW_{out}, PAR_i, PAR_d), albedo (α), etc.) and biochemical parameters ([CO_2], [O_3], [N_2], [NO_x], [NH_4], [NO_3]). Expected changes in these drivers are spatially heterogeneous across Europe (excluding CO_2) and will affect different ecosystems. We will need to consider their potential expected changes both spatially and temporally.
We can consider an ICOS station type network as a repetition of domains that are distributed among « control » and « exposed » areas. We can take benefit from the network to attribute the future changes in GHG balance to drivers cited above.

2. Short review: literature analysis
    a. Uncertainty in flux measurements using EC methodology

The eddy covariance (EC) method is the most direct and defensible way to measure vertical turbulent fluxes of momentum, energy and gases between the atmosphere and biosphere (Baldocchi 2014). Measurements are never perfect, due to assumptions, physical phenomena, instrument problems, and specifics of the particular terrain or setup. Different processing steps for fluxes computation (e.g. using different processing software or options) can produce a 5 % to 10 % difference in final fluxes using an identical raw data set input (Mauder et al., 2008). Moreover, several simultaneous raw data obtain from different sensors for one site can give a 10 % to 15% difference (similar processing) (Mauder and Foken 2006, Mauder et al. 2007, and Goodrich et al. 2016). The uncertainty of data recorded by an open-path CO_2 analyzer is likely to be larger than a site using a closed-path system. FCO_2 with the former requires information on H and LE. Thus, the uncertainties inherent in the measurements of H and LE will contribute to the final uncertainty of FCO_2. We are considering two error sources (Moncrieff et al. 1996): systematic errors (frequency response errors, physical consideration, instrument calibration, gas flux storage, u* filtering) and random errors (instrumental noise + stochastic nature of turbulence (Wesely and Hart, 1985) + change in footprint).
Considering an optimal measurement setup (as the ICOS network conception) and a standardised scheme for post-field processing of the measured EC raw data, we can assume that the systematic error is minimised, and then the random error of the fluxes is typically dominating the EC flux measurement uncertainty at short

timescales (for measured data only, which means excluding gap-filling error). The total random uncertainty associated with each 30 min run represents the standard deviation of the covariance and can be evaluated according to Finkelstein and Sims (2001) with a statistical approach named one-point sampling error approach. A daily differencing approach or self-differential approach (Hollinger and Richardson, 2005, Richardson et al. 2006) is also commonly used (e.g. in FLUXNET2015 dataset).
After discarding data using standard methodology of QA/QC tests (Mauder and Foken 2006) and u* threshold (Papale et al. 2006), the gap-filling is required for balance assessment for any time integration (daily, seasonally, yearly). This procedure is using some form of statistical, neural-network, parametric, or mechanistic models (Reichstein et al. 2005, Falge et al., 2001) that are also source of uncertainty on the final half hourly flux estimation. The uncertainty due to gap-filling is usually greater than the random measurement uncertainty (Figure 17, Wang et al. 2015).

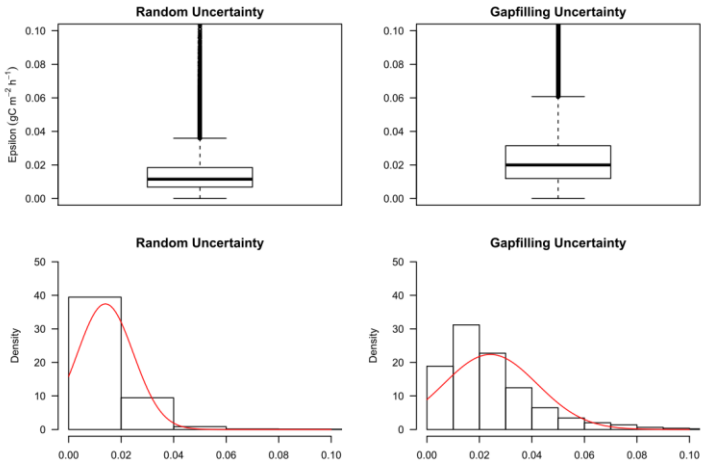

Figure 17. Example of uncertainty assessment for FR-Pue (mediterranean EBF) over the period 2001-2014. Random uncertainty is computed from Finkelstein and Sims (2001), the gap-filling uncertainty is provided by Reichstein et al. (2005).

Uncertainties in the u* threshold estimate represent one of the largest uncertainty components in the post-processing of NEE (Wutzler et al. 2018) and the higher is the u* threshold, the higher will be the amount of half-hourly data discarded, increasing the amount of data to gap-fill and therefore increasing the total uncertainty.

b. Error propagation

- Definitions (from Richardson et al. 2012).

Random errors accumulate “in quadrature” (the expected error on the sum ($x_1 + x_2$) is given by $\sqrt{\sigma_1^2 + \sigma_2^2}$), By comparison, systematic errors accumulate linearly (in this case, the expected error on the sum ($x_1 + x_2$) is simply ($\sigma_1 + \sigma_2$).

- Case study

We used 31 field stations from the FLUXNET2015 database to explore the error propagation of flux uncertainty over the period 1995–2015 based on half hourly data (measured and gap-filled) (Figure 18). The joint uncertainty gives the total uncertainty, as the combination of random uncertainty (Richardson et al. 2006) and the gap-filling uncertainty (u* filtering uncertainty).

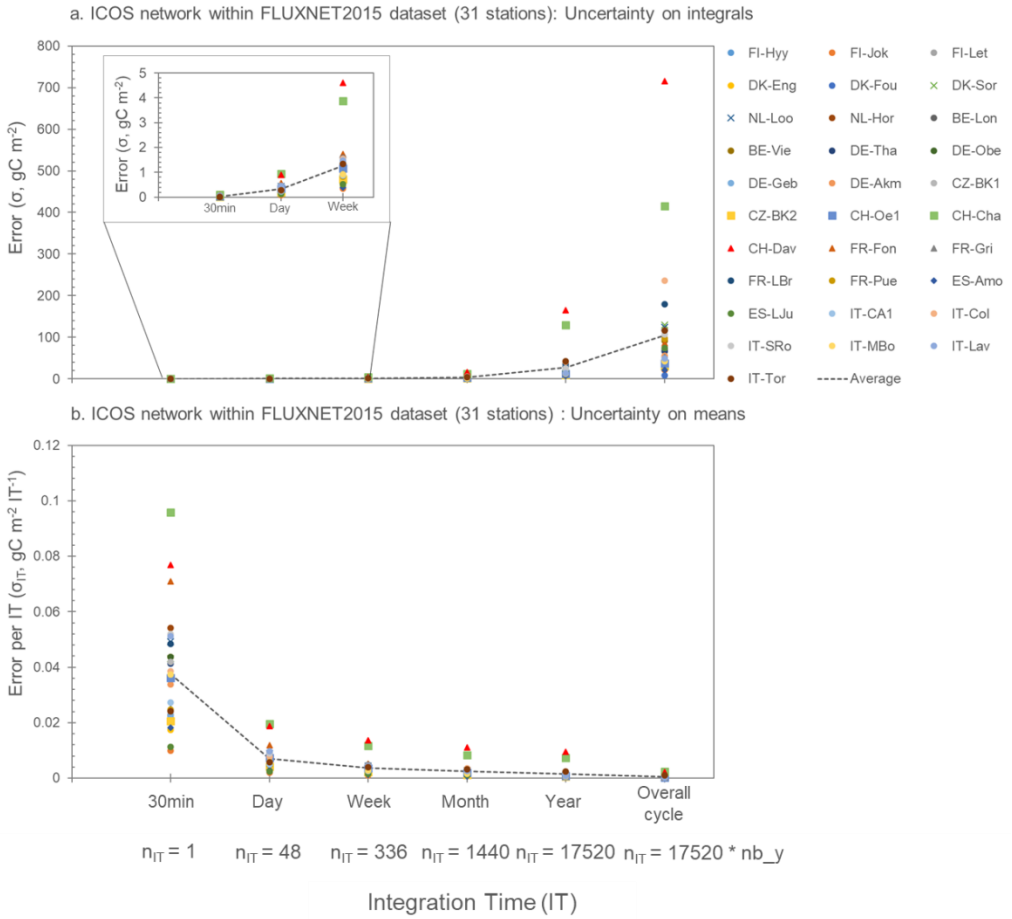

Figure 18 Error propagation in terms of total uncertainty (random + gap-filling) from FLUXNET2015 dataset (Richardson et al. 2006 + u* filtering) a. on integrals, and b. on means.

Looking at integrals over time (18a), the total random uncertainty increases with increasing time step, reaching 27.3 gCm^{-2} at the yearly integral, average for the 31 sites (min: 6.93 gCm^{-2} - max:165 gCm^{-2}). However, the precision of the measurements increases with increasing time integration (decreasing uncertainty on the mean, 18b).

In accordance with the previous studies, we showed that the random uncertainty is becoming insignificant relatively to the 30 min time step (18b), main average time considered for the EC flux computations. This means that averaging over n measurements improves the precision by a factor of $1/\sqrt{n_{IT}}$.

c. Statistical power of EC studies: time series and number of EC stations

Recent studies started to consider the spatial and temporal performance of a network within the context of detectable changes.

An interesting approach has been recently presented to show how many replications are needed for robust flux computation (Hill et al. 2017). However, spatial replication of EC system to accurately estimate a flux within an ecosystem is a challenge, especially due to high equipment costs. They defined the effect size by the magnitude of the difference in mean fluxes from two ecosystems, relative to the total measurement uncertainty. In this study, the flux uncertainty measurements were assessed using a self-referential approach (Richardson et al., 2006).

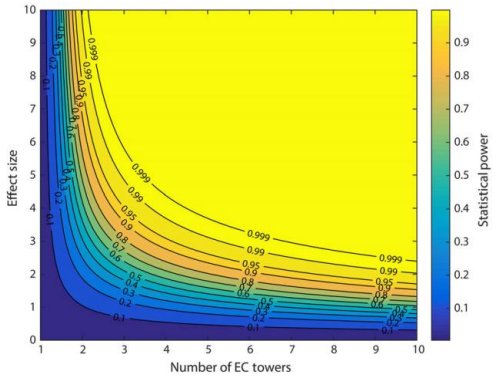

Figure 19. From Hill et al. (2017), Fig. 2. Statistical power, that is the probability of correctly rejecting the null hypothesis, H0, as a function of the effect size and the number of eddy covariance towers per ecosystem, where H0: there is no difference in the flux from the two ecosystems. The effect size is taken to be Cohen's d.

They showed that, for a typical ecosystem, around four EC towers are needed to have 95% statistical confidence that the annual flux of an ecosystem is nonzero (Figure 19). Furthermore, if the true flux is small relatively to instrument noise and spatial variability, the number of towers needed can rise dramatically.

In the meantime, considering one station, the length of the time series has a marked impact on how well we can detect temporal trends, or not (Shao et al., 2015). Using a Monte-Carlo simulation to derive the detectable thresholds for trends and interannual variability of the annual carbon fluxes, Baldocchi et al. (2018) found that measured trends of interannual NEE must exceed 7 $gCm^{-2}y^{-2}$ if the measurement error is 30 $gCm^{-2}y^{-1}$ and the time series is 8 years long for one to conclude that the noted variation is not due to randomness. If data records exceed 20 years, trends as small as 3 $gCm^{-2}y^{-2}$ can be detected whatever is the uncertainty (i.e., ± 10, ± 30, or ± 60 $gCm^{-2}y^{-1}$) (Figure 20).

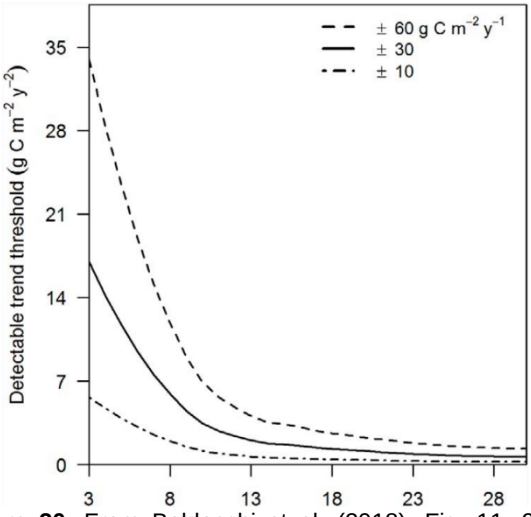

Figure 20. From Baldocchi et al. (2018), Fig. 11. 95% confidence intervals of trends in random time series of varying length and varying measurement uncertainty

3. Assessment of network capability: Case study in flux uncertainty computation

We plan to analyse theoretically the eddy covariance towers network performances for different cases ranged along an increasing complexity order. For this, we have assumed that the spatial domain considered, i.e. continental Europe, can be simplified as an ensemble of homogenous subdomains and ecosystems.

a. Theoretical approach with a hierarchical complexity

Simulated networks will evolve with a certain degree of complexity. This would support the assumption that homogenous measurements in terms of protocols and instruments must be put in place in ICOS and with other infrastructures. For each of the following case analyses, the relationship between error magnitude, number of stations and minimum detectable difference will be determined.

Case 1. uniform domain, uniform change.

Case 2. heterogeneous domain, uniform change

Case 3. uniform domain, heterogeneous changes – grouping by areas where change is uniform

Case 4. high level of complexity: heterogeneous domain, heterogeneous changes – grouping by areas where ecosystems and change are uniform.

The magnitude of the errors is purely theoretical in this first approach. We started the analyses with a simple theoretical case describing a change in annual NEE for a typical evergreen needleleaf forest presenting a "true" annual NEE of -300 gCm^{-2} and a change of +50 gCm^{-2} (Figure 21). Using statistical sampling of random synthetic annual NEE per number of stations (homogeneous network from 3 to 25 stations), we estimated the number of stations needed to detect a true change in NEE given the total uncertainty on this true value of each NEE of the network. This threshold was determined by the computation of the critical value (t-value computed representing the significance of the difference between the NEE and the NEE after a certain variation) and we compared it to the theoretical t-value according to the degree of freedom (df=number of stations - 1). We ran a bootstrap simulation with N = 1000 replications of random annual value of NEE and its variations to evaluate the threshold. The simulations begin with six levels of random uncertainties (i.e. ± 5, ± 10, ± 15, ± 20, ± 25, ± 30, 95 % CI) in the annual carbon fluxes.

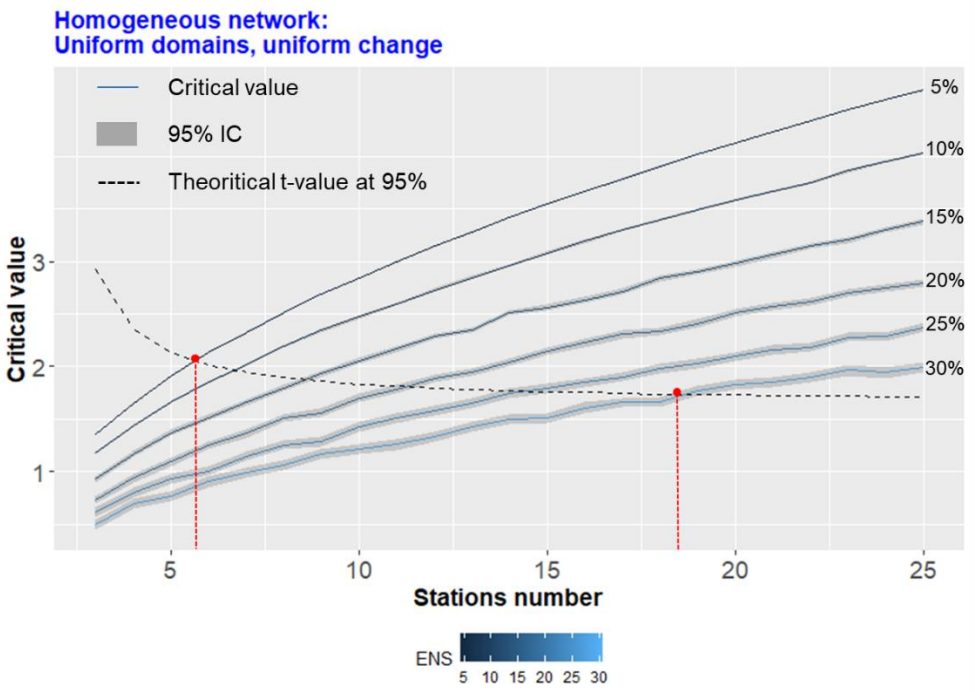

Figure 21. Critical values (t-value) computed for different level of uncertainty (ENS in %), with increasing the station number in the homogeneous network (line with their respective 95% IC). The dashed line indicates the reference t-value for the respective degree of freedom.

Figure 1 shows that for a change of +50 gCm^{-2} in an initial NEE of -300 gCm^{-2} (true value) with an uncertainty of ±5 %, we would need 5 stations in the homogeneous network to assume the change as a true change (significant difference with the initial NEE), and 17 stations for an uncertainty of 30 %.

b. "Real" errors expected from individual stations of the ICOS Ecosystem station network

Historical uncertainty analyses with heterogeneous network, over long chronological dataset available, as well as the historical changes are now under development.

4. Review of existing climate scenario simulations for the purpose of network optimization in Europe
   a. Physical components

Changes in meteorological parameters across Europe will be obtained from EURO-CORDEX simulations (Jacob et al. 2014), part of the CORDEX program. EURO-CORDEX aims at producing improved ensemble regional climate change projections for European land regions, based on multiple dynamical and empirical-statistical downscaling models forced by multiple global climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The variables will be extracted for the available most recent 'Representative Concentration Pathways' (RCP) scenarios (Moss et al., 2008). As a reminder, four basic sets

of scenarios were created, named after their total radiative forcing (in W/m²) in year 2100 relative to 1750: RCP8.5, RCP6.0, RCP4.5 and RCP2.6. RCP 8.5 represents very high greenhouse gas emission leading to 8.5 W/m² radiative forcing, which continues to rise even after 2100; RCP4.5 and RCP6.0 are stabilization scenarios, meaning that the forcings stabilize at their given value around the end of the century; and RCP2.6 represents an aggressive mitigation scenario with a considerable negative future emission.
We are looking for the best but, adequate, temporal and spatial resolution for projected variables. However, it should be considered that going towards finer time and spatial scale, the model results tend to become noisy. At this stage we are considering a daily time step.

b. Chemical atmospheric simulations

We are looking for a similar temporal and spatial resolution as for the meteorological parameters. Ideally, we should focus on daily simulations for the period 2020–2050 with a spatial resolution of 0.5°×0.5° and if possible 0.1°×°0.1° across Europe.
In terms of atmospheric chemistry trajectories, we are looking for:
- Concentration in O_3 (and/or if possible ozone deposition or PODY if it does exist in model outputs). PODY is a reference ozone metrics defined by the European Union (EU), and supported by the work of the Convention on Trans-boundary Air Pollution (CLRTAP) as an index based on stomatal O_3 flux (or uptake), where the functional (or physiologically effective) 'dose' of O_3 to which plants are exposed is defined as Phytotoxic Ozone Dose with a hourly threshold Y (PODY) (Ashmore et al., 2004, Anav et al. 2016).
- Concentration in nitrogen oxides (NO_x as NO_2)
- Nitrogen deposition (NH_4 et NO_3)

By now, what exists in terms of atmospheric projections is available within the 'Atmospheric Chemistry and Climate Model Intercomparison Project' (ACCMIP, Lamarque et al. 2013, Sicard et al. 2017). Data are available for downloading at: http://data.ceda.ac.uk/badc/wcrp-ccmi/data/CCMI-1/output/. These simulations were obtained for a low-resolution grid of 2° and especially for short time periods (2030–2035 and 2100–2105, see Sicard et al. 2017) and different models are used.
As we want to work at a higher spatial resolution, we are thinking about a partnership with the CNRM, using their chemical transport model (CTM) MOCAGE (Teyssedre et al. 2007). This model is able to simulate all these variables. In the meantime, we will start working with a simulation recorded by the CNRM on a continuous period of 1960–2100, for RCP6.0 at the 2° resolution and 6h temporal resolution, for the projections of O_3 et NO_2. We will test on this dataset the relevance of such requirement in terms of spatiotemporal resolution. Indeed, such requirement is highly time consuming, and the results produced could be noisy.

5. Next working steps

2018:

- We are pursuing our network performance analysis (phase A). From the theoretical approach and from the existing 2018 stations network, we can simulate or predict the potential changes in FCO_2 at each site and check whether the relevant explanatory variables are measured and available.
- We will define a domain in accordance to an ecoregion in reference to Hill et al. (2017) (Table 4). This implies that we can partition the European area within the ICOS network and potential extension, among homogenous zones being affected uniformly by the environmental changes.

Table 4. From Hill et al. (2017), Table 1. Total number of ecoregions per continent, the eddy covariance (EC) site years per continent, the total number of ecoregions sampled by EC and the percentage of a continent's ecoregions sampled

Continent	Ecoregions (#)	Site years (#)	Sampled (#)	Sampled (%)
Africa	126	151	11	9
Asia	276	1208	53	19
Australia	40	208	15	38
Europe	54	2033	30	56
North America	190	2627	68	36
Oceania*	38	26	2	5
South America	118	342	14	12
Antarctica	7	0	1	14
Total	849	6595	194	n/a

*Oceania excluding Australia.

- For each of the domain, we will explore the expected change in meteorological parameters as well as bio-chemical parameters and their potential impact on GHG fluxes, both in a literature review analysis and with model simulations.

2019-2020:

- We will compare the phase A results to these expected changes and explore attribution (phase B) of the impacts to changes in O_3 deposition, N deposition, Ta, radiation…. We will demonstrate which impacts can be detected and analysed causally using a statistical treatment based upon the degree of freedom of a variance decomposition model.

- 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.

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FLUXNET2015 dataset: http://fluxnet.fluxdata.org/data/fluxnet2015-dataset/
This work used eddy covariance data acquired and shared by the FLUXNET community, including these networks: AmeriFlux, AfriFlux, AsiaFlux, CarboAfrica, CarboEuropeIP, CarboItaly, CarboMont, ChinaFlux, Fluxnet-Canada, GreenGrass, ICOS, KoFlux, LBA, NECC, OzFlux-TERN, TCOS-Siberia, and USCCC. The ERA-Interim reanalysis data are provided by ECMWF and processed by LSCE. The FLUXNET eddy covariance data processing and harmonization was carried out by the European Fluxes Database Cluster, AmeriFlux Management Project, and Fluxdata project of FLUXNET, with the support of CDIAC and ICOS Ecosystem Thematic Center, and the OzFlux, ChinaFlux and AsiaFlux offices.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T3.5 by beneficiary 12-UAnt:
All activities will take place in the next 12 months.

Work Package 4: Improving Data

Lead Beneficiary: 1-ICOS ERIC

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.
The work carried out in WP4 during the first periodic reporting period (M1-M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

Contributions per task:

Task 4.1: Developing metadata for ICOS RI

Task leader: 1-ICOS ERIC
Beneficiaries involved in T 4.1: 2-UiB, 3-UNITUS, 4-UVSQ, 5-UHEI, 10-LU

Description of work carried out in T4.1 by beneficiary 1-ICOS ERIC

The ICOS facilities discussed at the two RINGO project meetings the need for a common metadata system across ICOS RI. Many tasks of ICOS and especially publication of the data and attribution and data usage tracking of this require a homogeneous and up-to-date common metadata set that describes the provenance of the data. As foreseen and planned, all Thematic Centers are still very occupied with the labelling process and gathering the actual metadata from the PIs, the unifying metadata set is still under design and only partly implemented in an ad-hoc style, like with the Ecosystem Thematic Center. ICOS CP hired a postdoc to lead

this task, in coordination with similar infrastructures like WMO, NEON and LTER, who started in September 2017.
An overarching setup has been designed by ICOS ERIC CP and a working group has been established with 20 representatives from all ICOS facilities that will further discuss, elaborate and implement this scheme. This will require to build adapters at each facility to allow the dynamic metadata exchange with Carbon Portal. In the second phase we consider to replace the adapters at Carbon Portal by direct interfaces at each facility with the ontology at CP. Most of the work of this task is expected to be performed as planned in the next reporting period (Figure 22).

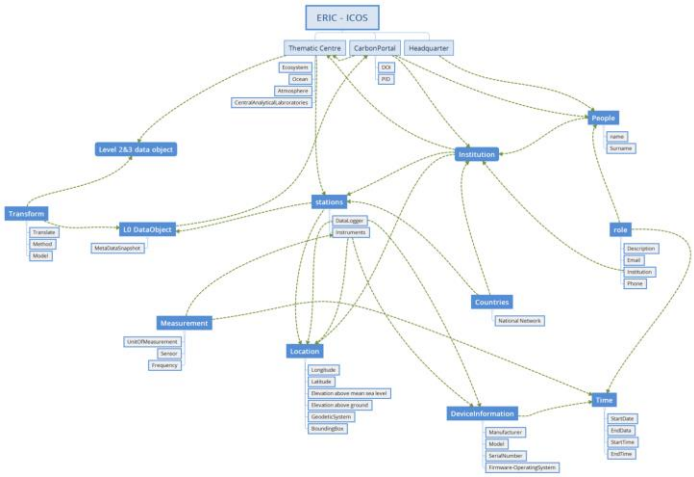


Figure 22 Schematic for the overarching ICOS metadata

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.1 by beneficiary 2-UiB

UiB participated in the discussion meetings at the RINGO meetings and started the transfer of data and metadata for a pre-ICOS L2 dataset for ingestion at Carbon Portal (MS17). UiB will participate in the Data Lifecycle Working group with 3 persons.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)

N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Description of work carried out in T4.1 by beneficiary 3-UNITUS

UNITUS participated in the discussion meetings at the RINGO meetings and started the transfer of data and metadata for L0 and NRT L1 datasets for ingestion at Carbon Portal. UNITUS will participate in the Data Lifecycle Working group with 2 persons.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the DoA

Deviations from the planned use of resources

No deviations from the DoA

Unforeseen subcontracting (if applicable)

N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Description of work carried out in T4.1 by beneficiary 4-UVSQ

UVSQ participated in the discussion meetings at the RINGO meetings and started the transfer of data and metadata for L0, NRT L1 and L2 datasets for ingestion at Carbon Portal. UVSQ will participate in the Data Lifecycle Working group with 3 persons.

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

No deviations from the DoA

Deviations from the implementation of task

No deviations from the DoA

Deviations from the planned use of resources

No deviations from the DoA

Unforeseen subcontracting (if applicable)

N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Description of work carried out in T4.1 by beneficiary 5-UHEI

UHEI participated in the discussion meetings at the RINGO meetings and started the transfer of data and metadata to the Atmosphere Thematic Center. UHEI will participate in the Data Lifecycle Working group with 2 persons.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.1 by beneficiary 10-LU

The work of LU in this task is integrated with ICOS CP and thus described in the first section of this task under ICOS ERIC.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Task 4.2: Making legacy data available

Task leader: 4-UVSQ, 3-UNITUS
Beneficiaries involved in T 4.2: 1-ICOS ERIC, 3-UNITUSINRA, 5-UHEI, 6-UVGZ, 11-ETHZEMPA, 7-RUG, 7-RUG_ECN, 23-GEOMAR, 9-UHEL, 9-UHELFMI, 14-OMSZ

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
MS17	Available data on long-term records of continuous greenhouse gas mole fractions and co-located flask samples compiled	WP4	5 - UHEI	18	Available data on long-term records of continuous greenhouse gas mole fractions and co-located flask samples compiled

Description of work carried out in T4.2 by beneficiary 4-UVSQ

We have downloaded the atmospheric CO_2 concentrations measured at the 10 stations over the period 2000–2015 from three existing databases: WMO/WDCGG, OBSPACK and CARBOEUROPE (Figure 23). In case of redundancy, we have compared the two or three time series in order to verify their consistency. More important, when available we have also downloaded the associated metadata describing analyzers and measurement protocols. In addition to the in situ measurements, we have downloaded flask measurements (NOAA/ESRL collaborative program) performed at four stations (Figure 24), as well as the results of the inter-comparison program organized every 4–5 years by WMO (Figure 25).
All those datasets described in the milestone MS17 represent the baseline of the work to be done in the coming year to explore data and metadata, with the objective to detect possible anomalies, and estimate associated uncertainties.

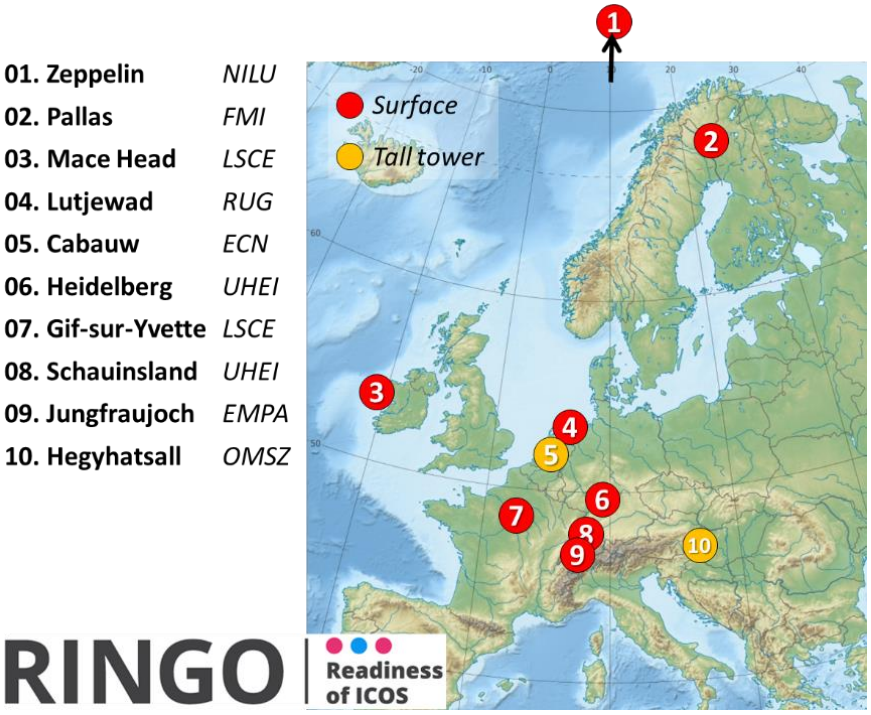


Figure 23: Map of the 10 stations involved in the re-analysis of atmospheric CO_2 dataset for the period 2000–2015

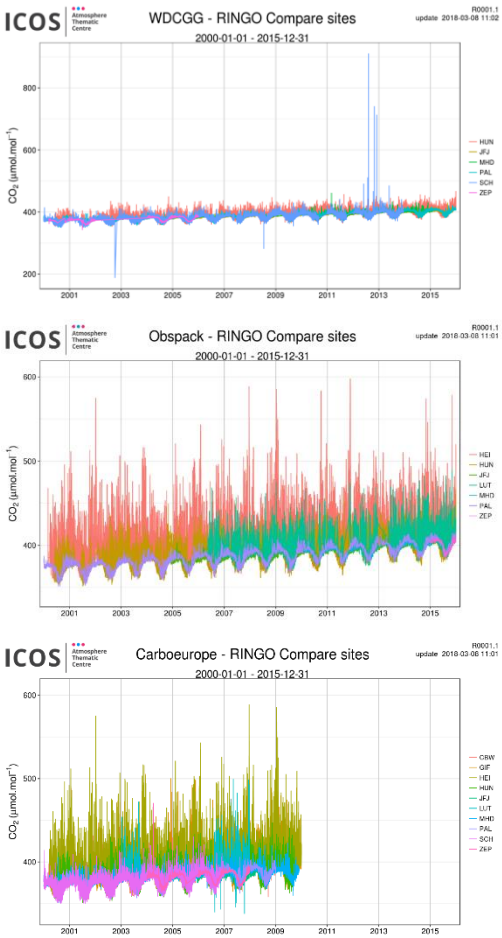


Figure 24: Atmospheric CO_2 concentrations at the stations involved in this task, from three databases: WDCGG (above), Obspack (middle) and Carboeurope (below).

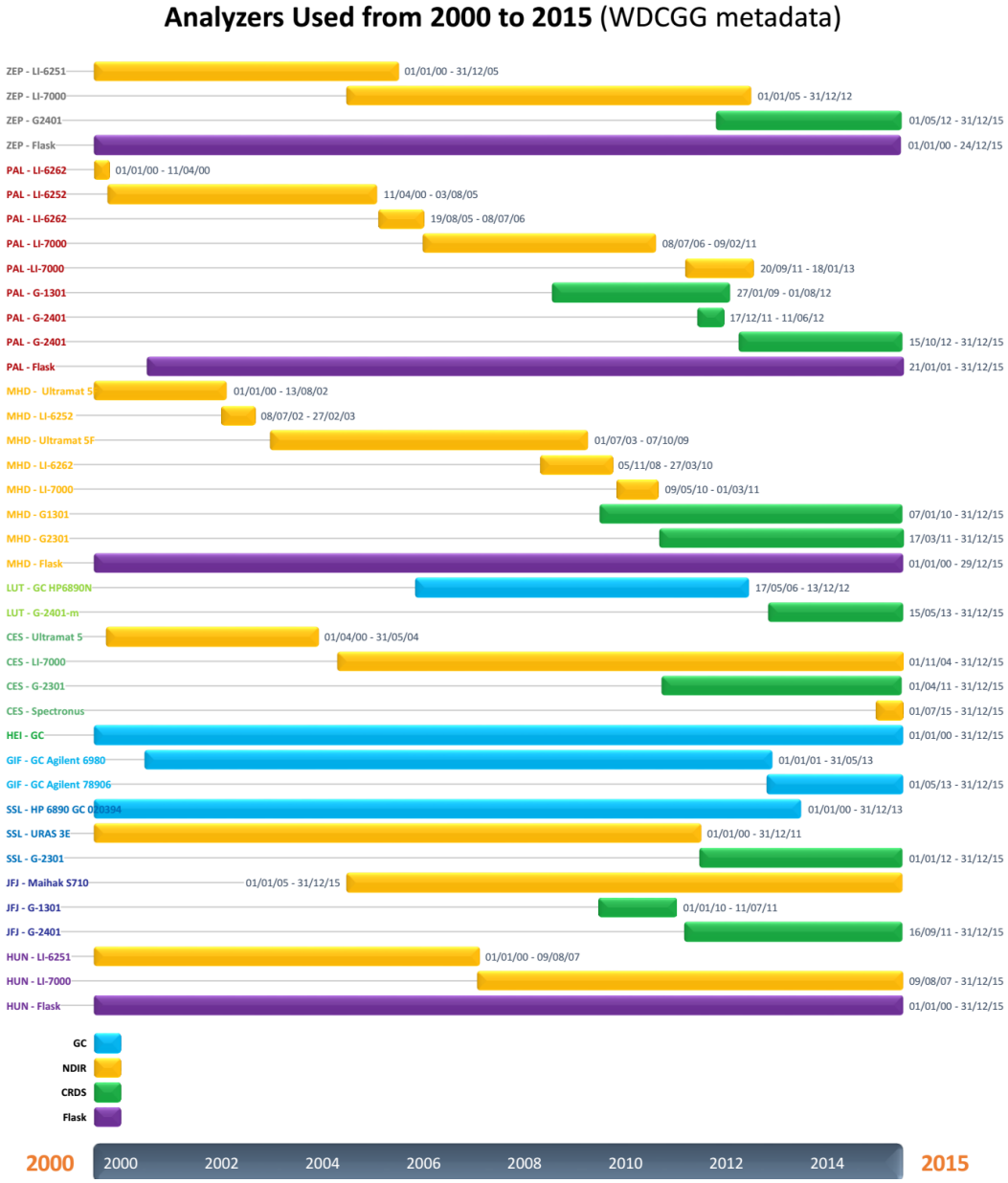


Figure 25: View of all analyzers and flasks sampling programs used at the 10 atmospheric stations over the period 2000–2015.

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

No deviations from the DoA

Deviations from the planned use of resources

The actual use of resources is in line with the planned use of resources concerning personnel costs. However, the actual use of resources for other direct costs is below the planned use of resources. We may file a request for a transfer of cost categories from direct costs to personnel costs during the next reporting period.

Unforeseen subcontracting (if applicable)

No unforeseen subcontracting in RP1 **Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)**

No unforeseen in-kind contribution from third party in RP1

Description of work carried out in T4.2 by beneficiary 3-UNITUS

The requirements of the sites to be used in the activity has been set: stations must be ICOS, with the ICOS setup in place, a long time series of data before ICOS setup with all the raw data and the metadata available. It would be important to have also a period of overlap between the original setup and the ICOS setup in order to evaluate changes and effect of standardization. On this basis, a call for contribution has been launched first among the RINGO participants and then extended to the other ICOS stations.
Since the sensors used in the past are heterogeneous, the first important step is to collect information about models and variables collected in order to define the variable naming convention and the metadata needed for the correct data processing. This activity started recently (after the selection of the stations) and is under development in order to allow the stations participating in the activity to prepare the raw data in the ICOS format. The difficulties in selecting the sites and defining the variables (old raw data and metadata are often difficult to find and not perfectly organized, with information still on paper) will require MS30 (wrongly reported under WP3 in the DoA) to be postponed by 4 months.
The processing codes are ready and the fine setup can be done only after the raw data preparation.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
Collection and preparation of raw data takes more time than expected and for this reason Milestone MS30 needs to be postponed by 4 months. This however should not impact the deliverable deadline.
Deviations from the implementation of task
None
Deviations from the planned use of resources
None
Unforeseen subcontracting (if applicable)
None
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
None

Description of work carried out in T4.2 by beneficiary 3-UNITUS_INRA

Linked Third Party INRA contributed to this task by finding the data and metadata for the activity.
Eddy-covariance datasets were selected for the linked third party INRA on two French forest ecosystems characteristic of two different climate regions: a Mediterranean climate and a temperate climate with a maritime influence, also considering two forest types: broadleaf evergreen and needleleaf evergreen. The data are now organised in order to make them available for full homogeneous re-processing.
Puechabon forest (ICOS code FR-Pue) coppice largely dominated by the overstorey tree *Quercus ilex.* Eddy covariance fluxes measured since July 1998, since 2014 with the ICOS compliant sensors. A period of 1 year and 3.5 months (from the 10th of September 2013 at 10:00 to the end of 2014) was covered with the old (LI-6262 + R3) and new (Li-7200 + HS-50) systems.
Salles forest (ICOS code FR-Bil), seeded with maritime pine (*Pinus pinaster Ait.)* in 2004, thinned and weedy vegetation cleared in 2008. Eddy covariance fluxes measured since 2000, since 2014 with the ICOS compliant sensors. Since 2014 the two systems run in parallel (with some differences in the measurement height in some periods)

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources

No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 1-ICOS ERIC

ICOS ERIC will coordinate the ingestion and publication of the datasets and their metadata from this task. In the next period the actual datasets that are now described in MS17 will be generated by the partners and ingested by Carbon Portal.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 5-UHEI

Beneficiary 5-UHEI contributed to Milestone MS17 by extending the ongoing CO2 time series for the Heidelberg station up to the end of 2017. The data have also been submitted to OBSPACK. The meta-data describing Heidelberg station and instrumentation have been reviewed and were found to be still valid for the current situation. We have also gathered the CO_2 QC records to be able to provide additional information for the uncertainty estimates. The Schauinsland PI was contacted and details among the CO_2 data and its comparison to the flask collected at SIL and measured in Heidelberg were discussed.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations
Deviations from the planned use of resources
Deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T4.2 was not available. The evaluation of existing data and gathering of QC data was therefore done by Ingeborg Levin (IUP) and Samuel Hammer (ICOS-CRL) using in-kind resources. The PMs of UHEI for T4.2 (2 PM scientist) will be transferred to 3 PM engineer (J. Della Coletta), who will take care of reprocessing the old Heidelberg CO2 data sets and evaluate the QC data.
Unforeseen subcontracting (if applicable)
No unforeseen subcontracting.
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

No unforeseen contribution from third party.

Description of work carried out in T4.2 by beneficiary 6-UVGZ

Two ecosystem sites with long datasets available have been identified – CZ-BK1 and CZ-wet. CZ-BK1 site data is available from 2004 with instrumentation change to ICOS standard in 2011. CZ-wet site data is available from 2006 with instrumentation change to ICOS standard in 2011. There is just a few months overlap of old and ICOS instrumentation in datasets of both sites. Both sites data and metadata are now organizing and formatting to follow ICOS standards.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 11-ETHZ_EMPA

ETHZ_EMPA provided all necessary information where the legacy data from Jungfraujoch are already publicly available. This is the case at several repositories. A thorough comparison of the data retrieved from the repositories was made and minor inconsistencies could be identified which jeopardized the perfect match of the data. In the case of Jungfraujoch, data are given in different time zones in the different repositories, which can easily lead to confusion. Close interaction with the task leader allowed solving these issues very timely and to complete the required metadata.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations
Deviations from the planned use of resources
No deviations
Unforeseen subcontracting (if applicable)
Not applicable
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
Not applicable

Description of work carried out in T4.2 by beneficiary 7-RUG, RUG_ECN

RUG has updated the metadata file of the historical Lutjewad observational dataset and submitted the latest CO_2 data for Obspack. Besides these, we have also submitted the CO_2 data to WDCGG.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 23-GEOMAR

The two ICOS sites with historic data have been selected and data and metadata are under organization. DE-Geb has continuous data since 2001.The setup is still in operation, measurements overlap with the ICOS setup from 12/2015 onwards.
Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 9-UHEL

The two ICOS sites with historic data have been selected and data and metadata are under organization.
FI-Hyy has continuous data from 4/1996 on, the EC setup has been largely the same all the time but measurement height was different 11/1998-6/2000. The setup is still in operation, measurements overlap with the ICOS setup from 4/2018 on.
FI-Sii data covers 3/2005-9/2015, no overlap with the ICOS setup (data submitted to ICOS from 6/2017 on, additional data from the ICOS setup can be recovered from 3/2016 on).

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a

Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 9-UHEL_FMI

We have provided CO_2 data to the WMO/WDCGG, OBSPACK and CARBOEUROPE databases together with metadata in this project. At Pallas station, independent measurements from the NOAA flask sampling network are available too. All these datasets described in the milestone MS17 represent the baseline of the work to be done in the coming year to explore data and metadata, with the objective to detect possible anomalies, and estimate associated uncertainties.
Finnish Meteorological Institute 9-UHEL_FMI is a Linked Third Party to 9-UHEL and contributes to MS17 by providing legacy data from the Pallas station.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T4.2 by beneficiary 14-OMSZ

OMSZ has provided all data and relevant background information including metadata for the joint activity in the framework of Task 4.2.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

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

Lead Beneficiary: 1 - ICOS ERIC

The main objective of WP5 are:

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

The work carried out in WP5 during the first reporting period (M1-M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary:

Task 5.1: Building stable cooperation with other regional observational networks

Task leader: (1) ICOS ERIC
Beneficiaries involved in T5.1: (1) ICOS ERIC

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

D5.1 Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO (M16)

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
MS13	Memorandum of Understanding for global cooperation drafted and start of negotiations with comparative regional networks	WP5	1 - ICOS ERIC	12	Memorandum of Understanding for global cooperation drafted and start of negotiations with comparative regional networks
MS14	Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO	WP5	1 - ICOS ERIC	16	Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO

Description of work carried out in T5.1 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC contributed to D5.1 (MS14) by organising and participating in negotiations between relevant parties, drafting the documents and promoting the joint benefits of this collaboration. Internal discussions with ICOS Research Infrastructure Committee and the Head Office defined the level and type of involvement of ICOS to GEO Carbon Initiative and the WMO program IG3IS. External discussions between GEO member organisations and the WMO considered the importance and role of these two global initiatives and the mutual benefits of ICOS involvement. ICOS ERIC organised a dedicated workshop during the 10th International Carbon Dioxide Conference and co-organised another workshop and exhibition ('ENVRI booth') in the GEO XIV Plenary to have wider participation in the discussions and to promote the visibility of these initiatives. One press release was written and published in the Copernicus newsletter in 2017. The results of these actions were summarised into the D5.1.

Beneficiary (1) ICOS ERIC contributed to Milestone MS13 by organising and participating in negotiations between relevant terrestrial in situ Research Infrastructures. The discussions considered on how to improve the current status of global carbon and greenhouse gas observation system to fill the identified gaps, and how cross-RI collaboration could best promote these actions. These first discussions contributed to the idea of the jointly written Memorandum of Understanding, and the discussions will be further continued along the project.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

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

Task leader: 2-UiB
Beneficiaries involved in T5.2: 10-ULUND, 3-UNITUS, 4-UVSQ, 8-NERC_UEA

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
MS24	Basic GLODAP and SOCAT services implemented at OTC	WP5	2 - UiB	18	Basic GLODAP and SOCAT services implemented at OTC

Description of work carried out in T5.2 by beneficiary 2-UiB

Partner UiB's main task within the first 18 months of the project were to prepare the integration of SOCAT and GLODAP routines into the OTC data management strategy (MS24) and data services. The second aim was to start the automation of the data submission dashboard for GLODAP data similar as it has been done for GLODAP.
GLODAP and SOCAT provide public access to quality-controlled, harmonized and integrated global collections of inorganic CO_2 chemistry data from the ocean interior and surface ocean. While data submission and integration within SOCAT has been streamlined via the SOCAT automation dashboard such routines are missing for GLODAP. Partner UiB and NOAA PMEL are organizing a series of workshops in week 39 of 2018 (24.-28.09.2018) where the technical and scientific aspects of the integration are being addressed. The first workshop, a dedicated quality control workshop aiming at gathering information about the various first and second level quality control procedures that are in place for the various parameters within GLODAP and to develop routines for underway parameters like pH and for coastal data, where routines are currently missing.

A second workshop deals with the technical integration of these and interoperability of data streams, assuring that US and European ICOS OTC programming efforts are aligned. A third GLODAP workshop will introduce the GLODAP automation routines to the GLODAP community and ensure that the dashboard is fit for purpose.
A programmer has been hired in 2017 and is working on the integration of quality control procedures of discrete measurements from GLODAP into the SOCAT automation dashboard. All code has been rewritten in Python and is being prepared for extending the SOCAT automation towards GLODAP needs.
UiB has been assisting and supporting the submission of ICOS and non-ICOS data to the past two versions of SOCAT and has been long-term archiving SOCAT data for the V5 and V6.
The Intergovernmental Oceanographic Agency of the United Nations Educational, Scientific and Cultural Organisation (IOC UNESCO) has the responsibility for the indicator 14.3.1 'Average marine acidity (pH) measured at agreed suite of representative sampling stations' and beneficiary UIB has been responsible to develop the data management methodology for the SDG target 14.3 'Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels'. A dedicated workshop in January 2018 at the UNESCO Headquarters addressed the methodologies and in March 2018 UiB advised UNESCO IODE (International Oceanographic Data and Information Exchange) addressed metadata issues and possible implementation on a global scale.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

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

ICOS CP worked together with the RINGO project partners to further streamline the ingestion system in ICOS to include the raw and quality-controlled datasets. All thematic centers now stream and publish raw sensor observation data and higher quality products through the ICOS data portal, including the most basic provenance metadata required for compliance with FAIR principles and Inspire. Further work to integrate the different metadata systems to better fulfill the full data FAIRness ambitions will be required in the 2nd half of the RINGO project.
The relevant metadata interoperability with the global networks has to be assured and therefore close contacts have been established with WMO GAW (WDCGG) and the WMO Data Expert group through participation in the workshops and meetings of: ORCID integration workshop (Espoo, 28–29 March 2017), GAW Symposium (Geneva, 10–13 April 2017), WIGOS Data Quality meeting (Geneva, 26–27 June), WMO GGMT (28–31 August, 2017), WMO World Data Center Expert Group (Oslo, 2–5 Oct, 2017) and the CEOS workshop on EO fossil fuel emission detection (Ispra, 18–19 June 2018), there also presenting the progress in ICOS and its data lifecycle.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA

Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T5.2 by beneficiary 3-UNITUS

The main activities in the first 18 months of the project have been focussed on two aspects:

1) the definition of an evolving strategy in order to harmonize the network in Europe. In fact, ICOS covers about 25–30% of the existing station in Europe and the best strategy for linking ICOS and the European Database must be developed. Discussions started in ICOS and technical solutions designed in order to have the two European systems fully compliant and easy to keep coordinated. This is a crucial and preliminary part in order to better organize the discussion with the extra-European networks.
2) the discussion with AmeriFlux (the largest network in the world together with the European) has been continued following the work initiated under the COOP+ H2020 project. A common GitHub repository for processing code is under finalization and will be released soon. In addition, common session at AGU and EGU have been organized where the collaboration of the two networks was strongly remarked. Also, for the AGU 2018 sessions involving also NEON have been organized.

The visibility on the collaboration activities will be used to encourage other networks, starting from the Australian OzFlux and the Chinese USCCC, to also work together and contribute to the common activity in order to arrive to a consolidated plan and first results in time for Deliverable D5.4

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Description of work carried out in T5.2 by beneficiary 4-UVSQ

ATC participated to the WMO GAW (Global Atmospheric Watch) international task force on low cost sensors for the measurement of atmospheric composition. It was co-author on low-cost sensor performance assessment and comparison with reference instruments. A document describing how reference instruments and low-cost sensors may be used together in a complementary way. The document includes guidance for procedures to ensure reasonable data quality, targeting new non-expert user-led applications and is IG3IS relevant.

ICOS ATC LSCE also participated to the GAW 2017 Symposium in Geneva, leading a discussion group on defining key requirements on data management for GAW as provider of science-based services. The goal was to inform data users and providers on the WIGOS metadata standard.
Also, ICOS ATC, together with the ICOS Atmosphere community at large, engaged the process to become a GAW contributing network**.**

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
The actual use of resources is slightly below the planned use of resources for now, but is foreseen to be in line as the project moves forward.
Unforeseen subcontracting (if applicable)
No unforeseen subcontracting
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
No unforeseen use of in kind contribution from third party

Description of work carried out in T5.2 by beneficiary 8-NERC_UEA

Beneficiary 8-NERC_UEQ contributed to task 5.2 by releasing two SOCAT versions, 5 in 2017 and 6 in 2018. In addition, SOCAT was registered as a Voluntary Commitment to the 2017 UN Conference for 'Annual, public SOCAT releases' #OceanAction20464 for the UN Ocean Conference. https://oceanconference.un.org/commitments/?id=20464 by Dorothee Bakker and the SOCAT Scientific Community on 9 June 2017. GLODAP was as well registered as a Voluntary Commitment to the 2017 UN Conference for 'Updates of GLODAP data product' #OceanAction21252 for the UN Ocean Conference. https://oceanconference.un.org/commitments/?id=20464 by UiB and GLODAP, the Global Ocean Data Analysis Project (Scientific Community) on 9 June 2017.
Partner NERC_UEA had outreach activities e.g. a keynote lecture on 'Quantification of the ocean carbon sink using surface ocean observations', and a-side event by IOC UNESCO's GOOS (Global Ocean Observing System) biogeochemistry panel IOCCP (International Ocean Carbon Coordination Project) with sessions on 1) SOCAT update and road ahead (Dorothee Bakker et al.), 2) GLODAP, 3) Data integration (Benjamin Pfeil et al.), at the Tenth International Carbon Dioxide, Interlaken, Switzerland, 23/08/2017; and a GOOS Webinar on the Surface Ocean CO_2 Atlas by Dorothee Bakker and Kim Currie, on 15 November 2017.
In addition, Dorothee Bakker attended the WDAC (WCRP) Data Advisory Council meeting at WMO (World Meteorological Organization) in Geneva, Switzerland, on 26–27 March 2018 and gave a talk on SOCAT and GLODAP.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)

N/a

Work Package 6: Management

Lead Beneficiary: (1) ICOS ERIC

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

The work carried out in WP6 during the first periodic reporting period (M1-M18) is shown below, including a description of the status of specific deliverables and milestones with contributions per beneficiary.

Contributions per task:

Task 6.1: Project financial and administrative management

Task leader: 1- ICOS ERIC
Beneficiaries involved in T 6.1:(1) ICOS ERIC

List of deliverables completed within this task within this reporting period:
D6.1 Organization of project Kick-off meeting, including an Executive Board and a General Assembly meeting (M3)
D6.9 Periodic Report 1 including request for first interim payment (M18)

List of milestones completed within this task within this reporting period:

Milestone	Milestone title	WP number	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Kick-off organized, including an Executive Board and a General Assembly meeting	6	1 - ICOS ERIC	3	Kick-off organized, including an Executive Board and a General Assembly meeting
MS28	Periodic Report 1 including request for first interim payment	6	1 - ICOS ERIC	18	Periodic Report 1 including request for first interim payment

Description of work carried out in T6.1 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC delivered D6.1. The RINGO project kick-off meeting was organised on 21–23.02.2017 in Heidelberg, Germany, hosted by Kirchhoff Institute for Physics, University of Heidelberg. The meeting aimed at providing the participants with a good overall information about managing and implementing the project, organizing the internal work plans for the project's six work packages and facilitating collaboration between partners. The first General Assembly Meeting and Executive Board Meeting were held at the end of the kick-off meeting. The kick-off meeting established a good working environment for the project and initiated good practises for internal project management.
Beneficiary (1) ICOS ERIC completed Milestone MS1, verifiable by the delivery of D6.1.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Task 6.2: Project scientific and progress management

Task leader: (1) ICOS ERIC
Beneficiaries involved in T 6.2: (1) ICOS ERIC

List of deliverables due to be completed within this task within this reporting period:
D6.5 Initial Risk Management Plan (M6)
D6.8 First Updated Risk Management Plan (M18)

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
MS5	Risk management plan	6	1 - ICOS ERIC	6	Risk management plan
MS27	First Updated Risk Management Plan	6	1 - ICOS ERIC	18	First Updated Risk Management Plan

Description of work carried out in T6.2 by beneficiary

Beneficiary (1) ICOS ERIC delivered D6.5 and D6.8. The Initial Risk Management Plan consisted of an evaluation of identified circumstances that would potentially pose risks for the implementation of the project; based on the initially foreseen risks in the project proposal writing phase and additional evaluation of Task level risks.
To manage the overall risks, an internal progress reporting and work planning schedules were implemented at the start of the project, asking the consortium to continuously monitor occurrences and communicate any occurrences that could be recognised as risks.
The Updated Risk Management Plan revisited the previously identified risks and evaluated the current situation. The updated plan identified a number of circumstances where potential unforeseen risks could materialise and proposed corrective actions to manage these circumstances; for example, detailed re-planning of timelines and recognition of potential need for commencing contract negotiations at earlier phase, re-allocation of tasks, sufficient communication, allocation of more time for foreseen procurement processes

already in the project planning phase, more targeted communication to consortium regarding the regulations related to Linked Third Parties and establishing more thorough information flows within the consortium.
Beneficiary (1) ICOS ERIC achieved Milestones MS5 and MS27, verifiable by the delivery of D6.5 and D6.7

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Task 6.3: Project internal communications

Task leader: (1) ICOS ERIC
Beneficiaries involved in T 6.3: (1) ICOS ERIC

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

D6.2 Project website and internal communication (intranet, email-lists, telephone connections) operational (M6)
D6.3 Project Dissemination Strategy (M6)
D6.6 First Updated Project Dissemination Strategy (M18)

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
MS2	Establishment of RINGO webpages as part of the ICOS website and internal communication	6	1 - ICOS ERIC	6	Establishment of RINGO webpages as part of the ICOS website and internal communication
MS3	Dissemination strategy	6	1 - ICOS ERIC	6	Dissemination strategy
MS25	First Updated Project Dissemination	6	1 - ICOS ERIC	18	First Updated Project Dissemination

Description of work carried out in T6.3 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC delivered D6.2, D6.3 and D6.6.

The project website (www.icos-ri.eu/ringo) has been published in February 2017. The website is integrated into the ICOS website and it is maintained by ICOS ERIC Head Office and Carbon Portal.
The initial Dissemination Strategy introduced key target audiences, communication channels and Exploitation Plan for the project, with the purpose of serving as a reference framework for evaluating the dissemination of activities.
The updated Dissemination Strategy focussed on streamlining the project dissemination with the ongoing development of the general ICOS communication strategy by for example evaluating target audiences and dissemination channels.
Beneficiary (1) ICOS ERIC achieved Milestones MS2 MS3 and MS25, verifiable by the delivery of D6.2, D6.3 and D6.6.

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

Task 6.4: Organization of data management

Task leader: (1) ICOS ERIC
Beneficiaries involved in T 6.4: (1) ICOS ERIC

List of deliverables completed within this task within this reporting period:
D6.4 Initial Data Management Plan (M6)
D6.7 First Updated Data Management Plan (M18)

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
MS4	Initial Data Management Plan	6	1 - ICOS ERIC	6	Initial Data Management Plan
MS26	First Updated Data Management Plan	6	1 - ICOS ERIC	18	First Updated Data Management Plan

Description of work carried out in T6.4 by beneficiary 1-ICOS ERIC

Beneficiary (1) ICOS ERIC delivered D6.4 and D6.7.

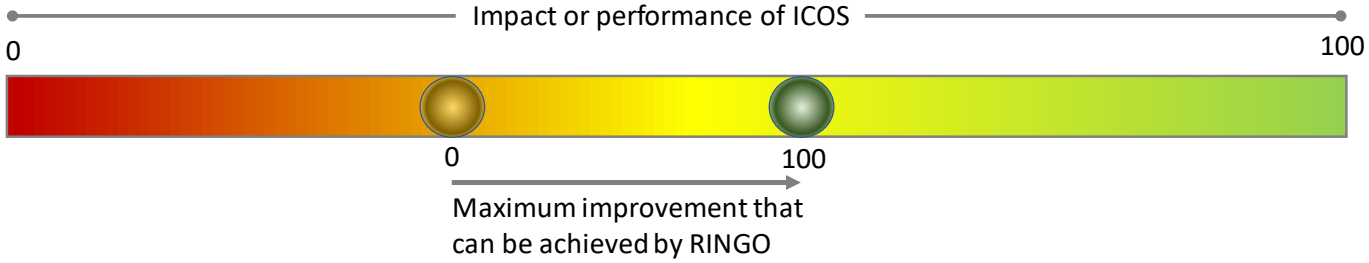
The initial Data Management Plan described the existing and planned data management, data access and data security policies of ICOS RI. It consisted of general descriptions of various different types of data: e.g. lab or field data, for example comparing performance of different instrumentation and/or methods or data generated in model tests or historical (so called legacy) data that may include evaluation of uncertainties. All of the abovementioned topics have been carefully explained with a general overview on the data management of the RINGO project as a whole, as well as a more detailed description of data management. The updated Data Management Plan has been constructed based on FAIR principle: Findable, Accessible, Interoperable and Reusable. Since each community follows its own conventions in file naming, it is crucial 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 open via the 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 is a long-term infrastructure that is foreseen to exist for at least 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.
Beneficiary (1) ICOS ERIC achieved Milestones MS24 and MS26, verifiable by the delivery of D6.4 and D6.5

Explain the reasons for any deviations from the DoA, the consequences and the proposed corrective actions.
No deviations from the DoA
Deviations from the implementation of task
No deviations from the DoA
Deviations from the planned use of resources
No deviations from the DoA
Unforeseen subcontracting (if applicable)
N/a
Unforeseen use of in kind contribution from third party against payment or free of charges (if applicable)
N/a

5. Impact

The impact of the project towards the development and readiness of ICOS as described in section 2.1 of the DoA continues to be highly relevant. Nevertheless, the internal impact assessment has been further developed in response to the remarks of the Evaluation Summary Report: "*The impacts section of the proposal is confusing in places and it is sometimes difficult to distinguish between the expected impacts of RINGO and those of ICOS. The use of measurable KPIs is a strength, but they are of variable quality with some, for example the number of industry contacts, not useful.*"
During the annual meeting in Antwerp in March 2018, the concept of distinguishing between the impact of the RINGO project on the readiness of ICOS and the impact of ICOS itself has been refined. The improved system enables to distinguish between the impacts of RINGO and ICOS while also taking into account that RINGO is responding to the specific scope of the INFRADEV call to individually support research infrastructures: "*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, definition of service level agreements and business/funding plan, outreach, and technology transfer activities*."

The improved concept of impact will therefore provide indicators of the impact of the project to the impact (or performance) of ICOS which can be depicted in the following graph.



As an example, the ICOS impact analysis defines the KPI 'Application of ICOS data in globally leading models' as an important impact of ICOS: "The indicator describes how ICOS data and models are used by the scientific community." The WP 4 of RINGO 'Improving data' aims at easing the access for ICOS data users through a harmonized common and consistent set of metadata. With that, it is directly targeting modelers as premium users for ICOS data. The work of the modelers to ingest ICOS data will be easier and data usage is likely to increase. The RINGO impact is not the whole process, but a specific step that is currently necessary to improve the impact of ICOS on the long run.
The following text is an upgraded version of the impact section of the DoA:

Expected impacts
The expected impact of the project is measured by developing a set of applicable KPIs in order to provide a harmonised and measurable data set about the achievements of the project.

Impact on the internal development of ICOS
The principles of using the KPIs as a monitoring methodology for the impact of this H2020 research project is a perfect test case for the general management approach of ICOS ERIC. With the implementation of selected KPIs, the methodology can be developed further and the concept can be refined and taken into use. The large number of project beneficiaries and linked 3rd parties mirrors the structure of ICOS as a distributed RI which is challenging in terms of coordination and management. This approach enables development of both the methodology and the indicators themselves simultaneously in an efficient and agile way. ICOS RI will improve and further develop efficient and harmonised management processes and methodologies by working together with both existing and new members. This will later enable the smooth transition towards a common way of working.
KPI used for measuring the impact of the proposal:

- Number and consistency of reports of performance provided during the project as important high-level record of the progress.
- Sub-KPIs:
  Number of persons trained by cooperation within the project

Remark: We agree with the reviewers that the impact of RINGO on the improvement of the ICOS-internal management is not well described here. We suggest to focus here on human capital. Thus, the Sub-KPI "Number of persons trained by cooperation within the project" should be kept, particularly with focus on people from candidate countries, while the overarching KPI focusing on reports should be abandoned.

Impact on membership and sustainability of ICOS ERIC
The project aims to enlarge the network of potential new members joining ICOS RI by involving interested countries in the activities of the WP2, thus enabling transfer of knowledge, contact and cooperation between the existing and new members aspiring to join. Establishing the contacts and learning to work together as a part of the network will increase the maturity level of the potential new members. ICOS RI will benefit from wider and enlarged geographical coverage by including countries such as Ireland, Portugal, Spain, Greece,

Hungary, Romania, Poland or Estonia. The project will have an extremely positive impact on membership and sustainability of ICOS ERIC. The countries aiming to join ICOS RI will have the possibility to further increase their maturity level and take steps for the full membership of ICOS ERIC. Increased geographical coverage supports the long-term sustainability of the entire infrastructure.
KPI used for measuring the impact of the proposal:

- Number of new countries in preparation of joining the ICOS ERIC.
- Sub-KPIs:
  Number of additional stations provided by new countries.
  Geographical coverage of the network.
  Number of persons trained.

Remark: no update of this KPI

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 standardization of the above approach will provide a basis for a continuous development and adoption of new techniques and thus secure the relevance and sustainability of ICOS ERIC.
KPI used for measuring the impact of the proposal:

- Number of new methods/parameters standardized and made operational within ICOS ERIC
- Sub-KPIs:
  Number of new instruments or methods tested
  Number of specifications or protocols developed

Remark: no update of this KPI

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 that is the high performance of ICOS in the specification of its stations and sensors that has been achieved during the past decade of developing this RI. During this process, the cooperation with sensor providers has been very close and ICOS internal studies have resulted in manifold developments on the company side. At the current state, the scientific base for the next technological developments has priority.
Nevertheless, during this development phase, ICOS will provide access for testing new instruments and transfer results in the framework of the permanent industry dialogue that is conducted anyway.
KPI used for measuring the impact of the proposal:

- Number of industry contacts during the development of future activities.
- Sub-KPIs:
  Number of physical access cases
  Number of results provided for further developments

Remark: according to the review this KPI is useless. Nevertheless, we will monitor the innovative impact coming out of WP 3. There has been already one connection to a company producing drones in the context of Task 3.1. Drones may improve the performance and findability of aircores.

Scientific impact
The consolidation of the well-established ICOS activities and the addition of high-quality data streams from novel platforms and parts of the three ecosystem domains previously not covered by measurements will help reducing the current uncertainties in the carbon budget estimates and stimulate the development of new scientific approaches. This will increase the scientific value of ICOS data and data products in global context, and provide the opportunity for ICOS to set standards for construction and operation of future cross-domain research infrastructures.
KPI used for measuring the impact of the proposal:

- Number of publications on global climate and biogeochemical cycles research in which ICOS has a key role;
- Number of publications on new scientific approaches based on newly available data types.

Remark: This KPI is indeed focussing too much on the general ICOS impact. We will, therefore, narrow the number of scientific publications to the outcome of the RINGO project including the availability of legacy data in Task 4.2.

Impact on a global in situ observation system on GHG

The involvement of ICOS in a global observation and information system on carbon and GHG can be measured by indicators that describe the degree of cooperation achieved with RIs on other continents, by the intensity of data flow into global integrations and by the amount of services ICOS provides to global data integration networks and to global initiatives such as IG3IS or the envisaged GEO flagship on carbon and GHG. However, none of these indicators can be defined as key indicator.

KPI used for measuring the impact of the proposal:

- Degree of connectivity of ICOS in global observation systems
- Sub-KPIs:
  Number of MoUs signed.
  Number of global data portals that are connected to ICOS via metadata

Remark: no update of this KPI

Societal impact

The main indicator for societal impact of ICOS is the degree of knowledge transfer to the main policy forums such as IPCC, GCP and UNFCCC. By providing access to high-quality data and data products in a transparent, well-organized and easily accessible way through the Carbon Portal, also the public will be able to relate better to climate science and monitoring. A key challenge will be to develop data products that are enabling to distinguish between natural processes and anthropogenic fossil fuel emissions and connect this knowledge to mitigation and adaptation activities. A deeper analysis will be conducted throughout the proposal.

KPI used for measuring the impact of the proposal:

- Measures of societal relevance of ICOS data and products (to be developed during the project).
- Sub-KPIs:
  Citation of ICOS-related publications in reports of IPCC, GCP and UNFCCC.
  Amount of data cites in respective reports
  Development of a general societal impact assessment scheme for ENV RIs in the ESFRI framework

Remark: An already tangible impact of RINGO is that it has enabled an impact analysis for ICOS. The impact analysis has defined 17 KPIs and conducted an evaluation.

6. Update of the plan for exploitation and dissemination of result

Include in this section whether the plan for exploitation and dissemination of results as described in the DoA needs to be updated and give details.

We presented the latest dissemination and exploitation strategy and results in D6.6 (Updated Dissemination Plan). This version was further streamlined with the general ICOS communication and dissemination strategy - development of which is ongoing and will be finalised during the duration of the project - with updated target audiences and dissemination channels. The updated version also lists dissemination activities and channels executed and utilised so far in the project.

One of the major points to take into account in this and the future versions of the Dissemination Strategy is the compliance with the new GDPR regulation. RINGO acknowledges the regulation and is taking the necessary actions to ensure compliance with it in all its dissemination activities.

The updated strategy also pooled together results disseminated so far in the project.

Dissemination and Exploitation activities in RINGO between 1.1.2017-30.6.2018

Type of activity	Details of activity	Coverage
RINGO news and events	News article 'RINGO Annual Meeting', Jan 2018	Global
RINGO news and events	News article 'Are you lost while trying to seek for the correct information?', Dec 2017	Global
RINGO news and events	News article 'RINGO Kick-off meeting in Heidelberg', Feb 2017	Global
ICOS Newsletter 2/2018	News article 'ICOS community meets at RINGO Annual Meeting', May 2018	Global
ICOS Summer Newsletter 2017	News article on project updates, July 2017	Global
ICOS Spring Newsletter 2017	News article 'RINGO launched in Heidelberg', April 2017	Global
EMDESK	EMDESK project management platform operational, internal materials continuously uploaded	RINGO Consortium
Kick-off Meeting	RINGO Kick-off meeting 21.-23.02.2017 Kirchhoff Institute for Physics, Heidelberg, Germany	Consortium level
Training and Workshops	Training workshops for scientists in candidate countries: Initial workshop on manager training for new countries Czech Globe, Czech Republic	Consortium level; WP2
TCCON and ICOS data integration workshop, June 9, 2018	In conjunction with the 2018 annual TCCON meeting, University of Mexico (UNAM, Universidad Nacional Autónoma de México) in Hacienda Cocoyoc, Cuautla, Mexico	WP1
TCCON and ICOS technical integration workshop		WP1
Skogaryd Research Catchment workshop June 2018	Skogaryd Research Catchment, University of Gothenburg, Sweden	WP1
Annual Meetings	RINGO annual meeting 20.-22.3.2018 University of Antwerp, Belgium	Consortium
ISI MIP and PROFOUND Cost action final workshop 9-10 October, 2017	Potsdam Institute for Climate Impact Research (PIK)	Participation (communications), WP3
AGU fall meeting 11-15 December 2017	New Orleans Ernest N. Morial Convention Center, USA	Panel session on "Integration of Ecosystem Research

		Infrastructures for Multi-Scale Analysis" WP5
GLODAP reference group meeting at the 2018 Ocean Sciences Meeting 11-16 February 2018	Oregon Convention Center, Portland	Participation; WP5
Deliverables published		
• Deliverable 2.2 Concept document on collaboration with countries and stations outside European Union	January 2018	
• Deliverable 2.4 Online platform as part of ICOS webpages including technical and scientific training material	December 2017	
• Deliverable 5.1 Concept for ICOS involvement in carbon and GHG flagship inside GEO and IG3IS program by WMO	April 2018	
• Deliverable 6.2 Project internal communication	June 2017	
• Deliverable 6.3 Initial Project Dissemination Strategy	June 2017	
• Deliverable 6.4 Initial Data Management Plan	June 2017	
• Deliverable 6.5 Initial Risk Management Plan	June 2017	
• Deliverable 6.1 Organization of project Kick-off meeting, including a General Assembly meeting and Executive Board Meeting	March 2017	

7. Update of the data management plan

The initial Data Management Plan described the existing and planned data management, data access and data security policies of ICOS RI. It consisted of general descriptions of various different types of data: e.g. lab or field data, for example comparing performance of different instrumentation and/or methods or data generated in model tests or historical, so called legacy data that may include evaluation of uncertainties. All of these abovementioned topics have been carefully explained with a general overview on the data management of the RINGO project as a whole, as well as a more detailed description of data management. The updated Data Management Plan has been constructed based on 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.

8. 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:
Task 1.1
M6:
Internal communication has been slower than expected, subsequently resulting in the need to extend the internal round for comments so that the milestone was achieved in M16.

M15 and D1.1:
The procurement process for sub-contracting the impact analysis was launched in July 2018 (Month 7) but had to be re-launched in September (Month 9) to fully comply with the Finnish national regulations for procurements. This caused some delay in Milestones M6 and M15 related to this task. The timeline for the thorough execution of the analysis was re-scheduled and the milestone will be finalized by 31.1.2019

The consequences of the delay are not critical. In fact, it fits even better in the time line of the further development of ICOS since the impact analysis will serve as one element of the updated strategy and is now in phase with other ICOS-internal processes to update the strategy (internal consultation with different bodies, external communication with users and stakeholders).

Task 1.2
Deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T1.2 (and T1.3, see below) was not available. The evaluation of existing data and modelling results was therefore done by Fabian Maier (Master student) and Samuel Hammer (ICOS-CRL) using in-kind resources. The PMs of UHEI for T1.2 (8 PM scientist) will be transferred to 12 PM engineer (J. Della Coletta), who will take care of the sampling site in Freinsheim and will measure and evaluate the $^{14}CO_2$ analyses on the flasks collected in Freinsheim.

Task 1.5
UAnt: The originally anticipated 12PM for a senior researcher (Post-doc) were converted into 23PM for a junior researcher (PhD-student). The total budget of the task remains however unchanged. This change has also no implication on the foreseen work plan and deliverables. It has been agreed with the coordinator and Project officer
UBremen: The work conducted up to now has been funded by institutional funding of the University of Bremen and not by the RINGO project. This had internal reasons. It was the only way to secure positions over the full duration of the project.
BIRA:
In the original plan, resources were allocated to the organisation of a workshop to discuss the integration of TCCON in ICOS. Since this workshop was replaced by a dedicated presentation with discussion followed by a breakout meeting during the TCCON annual meeting in Mexico these resources have been partially transferred to travel costs for this meeting in Mexico; these changes have been agreed with the coordinating team.
Task 2:1
ICOS ERIC: There was a slight deviation from the DoA on submitting the deliverable, that was delayed with one month due to changes in personnel and re-directing work resources.
Task 3.1
RUG: The first intensive campaign in Sodankylä was delayed by ~6 months, because there is no sunlight in Sodankylä winter.
BIRA: Bialystok measurements has not been started yet.
Task 3:2
IOW:
Beneficiary 27-IOW started with unforeseen delay into the project, as it turned out, the originally envisaged status as linked partner to partner 23 could not be realized due to unresolved legal issues. Therefore, IOW became full beneficiary as part of the amendment as of August 2017, and at the same time was assigned Task Lead of Task 3.2.
Planning of work towards Deliverable 3.2 (Baltic Sea) started immediately, but progress was slowed by two further unforeseen circumstances.

(c) The purchase of the instrument to be used on the Baltic line (by partner 1 – ICOS ERIC) was delayed due to issues between supplier and ICOS in general, as well as custom declarations etc. At the end, the sensor, which is the key component of the planned instrumentation, did not arrive at IOW before February 2017, i.e. month 14 of the project.
(d) Despite earlier request, communication and positive feedback from the ship's owner, additional instrumentation was finally not granted on VOS Finnmaid, despite the fact that the already installed seawater trace gas system is maintained for 15 years now, with excellent relation to the ship's crew. The reason has to be seen in new rules regarding personnel not hired by the company on the upper deck of the ship, and space requirements due to new required installation.

As the ship's surrounding might affect the structural design of the component's assembly, instrument development did not proceed as envisaged and work progress is behind plan. Still, strong efforts have and are being made towards the implementation on a suitable carrier in the Baltic Sea. The actions are summarized as follows:

- Need and requirements for the calibration gases has been discussed with the partners and ICOS CAL (UHEI). The calibration gases are at IOW now.
- Through discussions with members of the ATC, the design of the system has been finalized and most parts have been recently ordered. Using the ICOS network proved tremendously helpful for the design and ATC-specific recommendations.
- Potential options for autarkic data transfer from/to the ship have been identified by IOWs marine instrumentation group.

- Alternatives for a suitable ship of operation have been sought and identified. Through the network of the Alg@line and BONUS INTGRAL networks, contact was made to the ship's owner of VOS Tavastland, commuting between Helsinki and Umea and back on a weekly basis. The ship is instrumented with a GO-type pCO_2 system by SMHI, and would be the ideal platform for the planned atmospheric work. The instrumentation on Tavastland is currently discussed as additional ICOS Ocean component from Sweden. Negotiations look promising, but are not finalized yet.

So despite the delay, it is envisaged that the goals within Task 3.2 can be met without losses.
Due to the reasons above, the purchase of components for the peripherals of the system has been delayed with most of the procurements to be paid in the 2nd reporting period. Use of personnel is slightly behind original plan due to the same reasons. This situation will be corrected over the next reporting period

ICOS ERIC:
Procurement, due to general considerations in the relation between instrument supplier PICARRO and ICOS-ERIC, took longer than expected. Also, some difficulties in connection to customs and transport caused further delay. The sensor was finally delivered to partner IOW in month 14 of the project.
While ICOS-ERIC fulfilled their duties within Task 3.2., the delay in sensor procurement, together with other issues, affected the work plan of partner IOW.
UVSQ:
Due to difficulties to elaborate a final partnership agreement between LSCE authorities and the Compagnie Maritime Nantaise who is owner of the Colibri ship, the equipment have not yet been installed aboard. The main problem relies on the insurances policies where a common agreement has to be found between both parties. There have been several interactions between both partners which took quite some time but the latest news are constructive and we hope to be able to solve this last critical point beginning of autumn and then to install and run our equipment by the end of the year (depending on the opportunity given by the vessel staying on harbor).
Due to the above-mentioned reasons, the actual use of resources of other direct costs is below the planned use of resources. In order to correct this situation, we may file a request for a transfer of cost categories from direct costs to personnel costs during the next reporting period.
However, concerning personnel costs, the actual use of resources is in line with the planned use of resources.
GEOMAR:
The VOS line M/V Atlantic Cartier went out of service in summer 2017 and all equipment had to be removed from board. We were promised by the ship's owner to be able to move to the replacement ship M/V Atlantic Sail in 2017. Due to enormous problems with this new built ship we couldn't start the installation on board the M/V Atlantic Sail before June 2018. The installation is nearly finished and we plan to start the measurements in August 2018. This will delay our tasks within RINGO but will not hinder us from fulfilling our tasks within the project time.

Task 3.3
NERC_UoE:
The instrument is delayed in lab tests whilst we correct an issue with pressure and flow rates. We are working to resolve these issues at present and aim to, once corrected, integrate the instrument into a ASV during the summer months.

Task 4.2
UNITUS:
Collection and preparation of raw data takes more time than expected and for this reason Milestone MS30 needs to be postponed of 4 months. This however should not impact the deliverable deadline.
UHEI:
Deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T4.2 was not available. The evaluation of existing data and

gathering of QC data was therefore done by Ingeborg Levin (IUP) and Samuel Hammer (ICOS-CRL) using in-kind resources. The PMs of UHEI for T4.2 (2 PM scientist) will be transferred to 3 PM engineer (J. Della Coletta), who will take care of reprocessing the old Heidelberg CO2 data sets and evaluate the QC data.

Use of resources

The table below shows any significant deviations from the planned usage of resources for partners until now (Actuals) and the budgeted person months over the whole project; together with explanations.

	WP1	WP2	WP3	WP4	WP5	WP6	Total PMs per Participant	Explanation for deviation
5 - UHEI	14.00	0.00	0.00	5.00	0.00	0.00	19.00	Personnel costs were paid by the partner itself as recruitment of personnel intended for the work was delayed. Allocated PMs will be spent and reported in the next period.
Used	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Remains	14.00	0.00	0.00	5.00	0.00	0.00	19.00	
· UGOT	1.00	0.00	0.00	0.00	0.00	0.00	1.00	LTP UGOT have a total budget of EUR 11 175 and estimated only EUR 3000 for Other direct Costs. Direct costs for especially travel costs showed to be higher than estimated so therefore budget was transferred from budget category Personnel costs to Other direct costs. Personnel costs is instead covered from the University as responsible researcher Leif Klemendtsson is Faculty staff.
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	
· UBern	0.00	0.00	2.00	0.00	0.00	0.00	2.00	Up to now we were not able (due to time restrictions) to attend any Ringo meeting in person, therefore no travel costs. Furthermore, we only have very limited person-months available and this will be taken in one of the next financial periods.
Used	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	
12 - UANTWERPEN	12.00	0.00	1.00	0.00	0.00	0.00	13.00	Changes from other direct costs to direct personnel costs, PMs changed to 24 instead of 13. 12 PMs remain
Used	12.00	0.00	0.00	0.00	0.00	0.00	12.00	

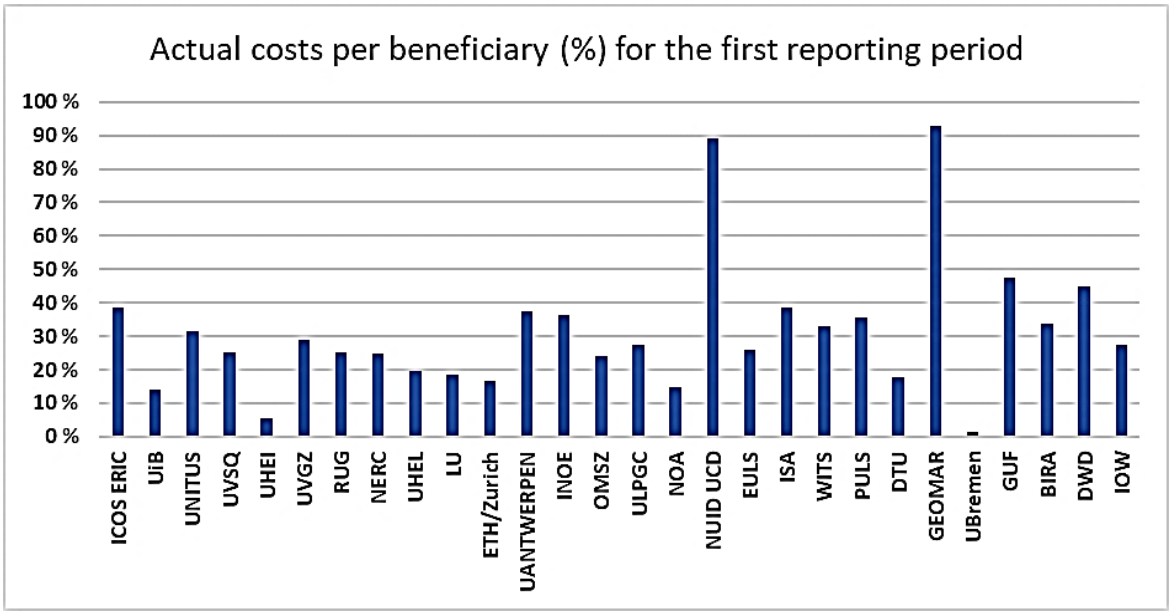
Remains	0.00	0.00	1.00	0.00	0.00	0.00	1.00 (12)	
16 - NOA	0.00	4.00	0.00	0.00	0.00	0.00	4.00	We put as first priority to use during the first period the limited resources of money for participation in Ringo meetings and summer schools. We decided to save the money for salaries for the second reporting period. Personnel costs for the people participated to summer schools and meetings were covered by other funds of NOA.
Used	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	PI concentrated the tasks into a shorter period rather than having it extended for the duration of the project.
Used	0.00	8.83	0.00	0.00	0.00	0.00	8.83	
Remains	0.00	-5.83	0.00	0.00	0.00	0.00	-5.83	NB. the budget has not been overspent, only PMs reported inconsistently
23 - GEOMAR	0.00	0.00	8.00	0.00	0.00	0.00	8.00	All budgeted PMs used, explanation not given
Used	0.00	0.00	8.00	0.00	0.00	0.00	8.00	
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	We receive money from the University of Bremen and use this money to complement project funding as well as for covering unexpected costs, e.g. broken instruments. During the reporting period we were able to put funding from the University of Bremen in the RINGO project. Since it is not foreseeable if we will be able to do this also in the future, we decided to save the RINGO money for "Direct personnel costs" for the remaining part of the project. Hence the personnel costs were covered by internal funding from the University of Bremen.
Used	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Remains	8.00	0.00	5.00	0.00	0.00	0.00	13.00	

Total used resources in the project between 1.1.2017-30.6.2018
Person Months:

Total Person/Months	125,00	78,00	120,00	90,00	40,00	18,00	471,00
Total Person/Months Used	44,79	31,31	66,44	23,84	8,87	11,68	186,93
Total Person/Months Remains	80,21	46,69	53,56	66,16	31,13	6,32	284,07

Actual costs per beneficiary (%):



Explanations on transfers between cost categories:

1. BIRA requested to shift 2250€ from other direct costs to travel, specifically to attend the annual TCCON meeting 2018 which was held in Mexico. This was based on the fact that WP1, task 1.5 is about the integration of TCCON in RINGO. The concept and consequences must be discussed with the TCCON partners (about 20 different institutes worldwide). Therefore, the best opportunity to have this discussion was to have it during the annual TCCON meeting that is attended by (almost) all TCCON partners. At the time of writing the RINGO proposal, it was not yet known that the 2018 annual TCCON meeting would take place in Mexico (each year, the TCCON meeting happens at another location). The budget transfer and travel outside EU was approved by the RINGO PO via an email (via ARES) on 16.4.2018.

2. UAnt requested to shift 9000€ from other direct costs to direct personnel costs. This was based on the fact that in WP1, task 1.5 (subtask 3) it had become necessary to hire a PhD student instead of the originally anticipated Post doc that was mentioned in the DOA. The reason is that there was a very suitable PhD student (with forestry engineering background) at the time while the foreseen post doc left the laboratory.

This meant that the number of person months increased from the originally allocated 13PM for post doc to 24PM for a PhD student. This budget- and PM shift was approved by the RINGO PO via an email on 27.4.2018.

3. UHEI reported that deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T1.2 (and T1.3, see below) was not available. The evaluation of existing data and modelling results was therefore done by Fabian Maier (Master student) and Samuel Hammer (ICOS-CRL) using in-kind resources. The PMs of UHEI for T1.2 (8 PM scientist) will be transferred to 12 PM engineer (J. Della Coletta), who will take care of the sampling site in Freinsheim and will measure and evaluate the $^{14}CO_2$ analyses on the flasks collected in Freinsheim.

4. UHEI reported that deviations from the planned use of resources occurred because the experienced Post Doc (S. Vardag), whom we wanted to employ for the work in T1.3 (and T1.2, see above) was not available. The evaluation of existing data and modelling results was therefore done by the PI (I. Levin) using in-kind resources. The PMs of UHEI for T1.3 (6 PM scientist) will be transferred to 9 PM engineer (J. Della Coletta), who will take care of, measure and evaluate the $^{14}CO_2$ analyses on the flasks collected at the Heidelberg pilot station.

5. LTP UGOT reported that as they have a total budget of EUR 11 175 and estimated only EUR 3000 for Other direct Costs. Direct costs for especially travel costs showed to be higher than estimated so therefore budget was transferred from budget category Personnel costs to Other direct costs. Personnel costs is instead covered from the University as responsible researcher Leif Klemendtsson is Faculty staff.

9. Unforeseen subcontracting

Not applicable

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

Not applicable