National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

The UK Integrated Carbon Observation System (ICOS)

Report to Marine Science Coordination Committee

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Report input:
UK-ICOS community (Appendix 1)

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1. Executive Summary

[1] ICOS (the Integrated Carbon Observation System) is a European Research Infrastructure (RI) identified as part of the European Strategy Forum on Research Infrastructures (ESFRI) process. It consists of a network of European observing systems operated at member state level and is underpinned by thematic centres (ocean, atmosphere and ecosystem [terrestrial biosphere]), a centralized administration and a database facility, both located in Helsinki. The UK is supporting the Ocean Thematic Centre (OTC) jointly with Norway. To date the UK greenhouse gas community (consisting of marine, terrestrial ecosystem and atmospheric scientists) has: formed a committee (Appendix 1) to organize the UK ICOS activities; shortlisted stations for ICOS submission (Appendix 2); and is currently discussing which stations will have full / associated status. We now need to address the funding issues to allow the UK to become a member of the ICOS-RI.

[2] In this report we discuss the:

- ***Scientific context*** underpinning ICOS
- ***Organization and remit*** of ICOS-RI
- ***Benefits*** of becoming a member of ICOS
- ***ICOS – UK relationship***
- ***Financial implications*** of UK membership of ICOS

Finally we make strategic recommendations to MSCC detailing the next steps that, from the perspective of the UK-ICOS science community, are key to secure the future of the observing stations and facilitate the membership of the UK in the ICOS-RI.

2. The science underpinning ICOS

[3] Carbon dioxide (CO_2) release to the atmosphere by human activity, including fossil fuel combustion, cement production and changes in land use patterns, has resulted in a 40% increase in atmospheric CO_2 concentration, from 280 ppm (parts per million; equivalent to µmol mol^{-1}) in preindustrial times to 400 ppm today. This increase has caused a measurable increase in global surface temperature, with significant consequences for human wellbeing predicted to occur when temperature increases exceed 2°C (from pre-industrial times), a threshold likely to be broken this century. CO_2 is not the only gas to cause radiative forcing of the climate. Methane (CH_4), nitrous oxide (N_2O) and a range of other greenhouse gases (e.g. SF_6, NF_3, (PFCs (perflurocarons), CO and H_2) also play direct and indirect roles in atmospheric warming. These are collectively known as greenhouse gasses (GHGs).

[4] The rate of increase in atmospheric GHGs would be significantly larger (and the time when the 2°C threshold is breached would be significantly sooner) had the ocean and terrestrial ecosystems not had the ability to absorb much of the emitted gases. Most recent scientific analyses estimate that roughly 56% of CO_2 emitted to the atmosphere has been absorbed by the oceans and terrestrial ecosystems over the past decade[1]. In the case of the oceanic absorption, this is causing a decrease in the observed pH of the surface ocean. This is known as ocean acidification and is predicted to have major, mostly detrimental, impacts on marine ecosystems. The nature, stability and persistence of the terrestrial and ocean carbon sinks, together with our emissions' policy, will regulate the future evolution of our climate, and the impacts on marine and terrestrial ecosystem function.

3. ICOS-RI

[5] Identification and quantification of the nature, size and variation of GHG sources and sinks demands a sustained programme of internationally coordinated observations, especially given that greenhouse gas uptake often occurs in regions distant from the associated emission (the ocean carbon sink is predominantly located in international waters). Within Europe this coordination is undertaken via the Integrated Carbon Observation System (ICOS).

[6] ICOS consists of two elements, firstly a series of observing stations in the three key realms (atmosphere, ocean and terrestrial ecosystem), and secondly a set of supporting coordination actions (via thematic centres) which underpin these systems.
Scientifically ICOS aims to:

- ***Track carbon and GHG fluxes*** in Europe and adjacent regions by monitoring the terrestrial ecosystems, atmosphere and oceans through integrated networks,

[1] Le Quéré, C *et al.* (2015). "Global carbon budget 2014." Earth Syst. Sci. Data 7(1): 47-85.

- ***Provide the long-term observations*** required to understand the present state, and predict future behaviour of the global carbon cycle and greenhouse gas emissions,
- ***Monitor and assess*** the effectiveness of ***carbon sequestration*** and/or ***greenhouse gas emission reduction activities*** on global atmospheric composition levels, including attribution of sources and sinks by region and sector[2].

[7] From a coordination perspective ICOS aims to:

- ***Harmonize research and measurements*** of greenhouse gasses across Europe,
- ***Increase the usability*** of research data for the benefit of science and society.

[8] Stations within the ICOS-RI will be predominantly based in Europe and its adjacent regions in order to deliver the above aims [6]. Large areas of the ocean and atmosphere are beyond national jurisdiction and therefore monitoring beyond exclusive economic zones/ national airspace is needed. To this end some stations, proposed as part of the UK submission to ICOS, particularly in the ocean sector, are located more remotely from the UK, for example in the North Atlantic Ocean.

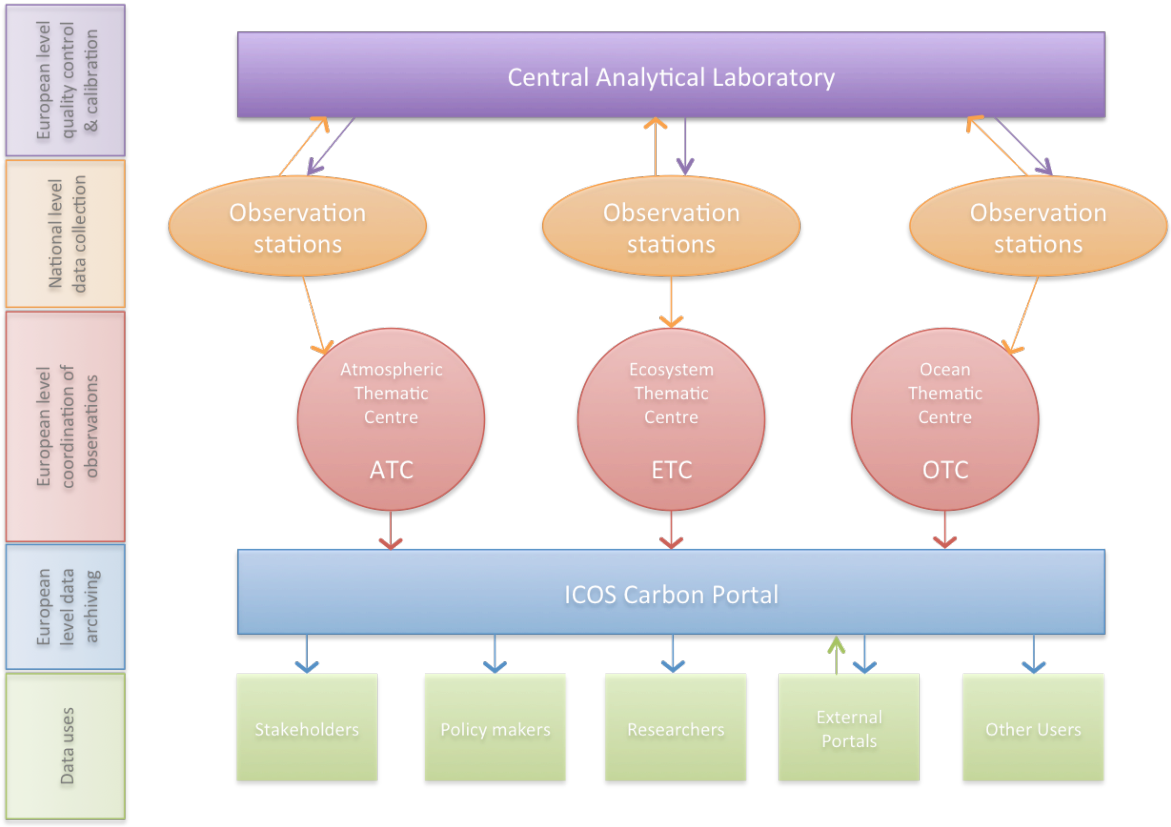

Figure 1 Organisational structure of ICOS-RI

[2] www.icos-infrastructure.eu

[9] Figure 1 above, shows how the different aspects of the ICOS research infrastructure interlink and facilitate information flow and data coordination. ICOS membership contributions are paid at the member state level. Membership of ICOS grants access to:

- The ***Central Analytical Laboratory (CAL)***. This ensures the accuracy of observational data, thorough quality control and routine testing of air sampling material. In addition, the CAL provides reference gases for routine calibration of in-situ measurements performed at the continuous monitoring stations. The CAL is hosted by Germany.

- The ***Atmospheric, Ecosystem and Ocean Thematic Centres*** (ATC, ETC, OTC). The thematic centres coordinates, standardizes protocols, and quality controls data produced by ICOS stations and submitted to the ICOS RI.

- The ***ICOS Carbon Portal***. This is a central data archive for all ICOS quality controlled data. The ICOS Carbon Portal offers easy access to research data from and for ICOS scientists all over Europe, as well science and education products, including flux maps in time and space, and material for policy makers, teachers and outreach activities.

4. Benefits of becoming a member of ICOS

[10] By becoming a fully paid member of ICOS the UK will benefit from access to:

- Harmonised ***cutting-edge GHG measurement techniques*** and processes,
- ***Up-to-date information*** on the activities in ICOS RI,
- ***Support for station instrumentation***, protocols and training,
- ***Harmonized and processed data*** from world class monitoring stations,
- ***EU capital funding*** available through the EU Infrastructure roadmap,
- ***National capital funding*** available through the UK RI roadmap.

[11] More specifically the UK will benefit in the following ways:

1. Individual UK monitoring stations will have ***access to the EU ICOS infrastructure*** and the associated benefits of the CAL, Thematic Centres and Carbon Portal (see [9] above), on a station by station basis,
2. The UK science community as a whole will participate in the ***allocation of capital***, ***leveraging of EU funding*** and GHG accounting at a European level,
3. UK scientists will ***create new, and maintain existing, strong research collaborations*** with other European scientists. These collaborations and research will keep the UK at the forefront of global GHG research,
4. Enable the UK to continue its leading role in international climate change science, ***engaging and influencing national and international policy and governmental negotiations***.

5. ICOS and the UK

[12] There are two elements to the involvement of the UK within ICOS-RI:

1. The commitment to ***co-host the Ocean Thematic Centre*** [13]
2. The ***science contribution*** to ICOS-RI [14].

[13] The UK, via the National Oceanography Centre, University of Exeter and Plymouth Marine Laboratory, is committed to ***co-host the ICOS Ocean Thematic Centre*** jointly with Norway. The UK will focus particularly on the delivery of:

- ***An operational network of Voluntary Observing Ships***
  Ongoing work in this area includes that undertaken by both the University of Exeter [UK-Caribbean line] and the National Oceanography Centre (NOC). The NOC is working with shipping companies to improve links and communication between the research and maritime sectors. To this end a meeting is being planned bringing together shipping companies and the scientific community. This will be held at Lloyds Register, Southampton in October 2015.

- ***GHG data product development***
  The Surface Ocean CO_2 Atlas (SOCAT), which provides global synthesis products of surface ocean fCO_2 (fugacity of CO_2) upon quality control. SOCAT version 3 (to be released on 7 September 2015) has 14.7 million fCO_2 values for the global oceans and coastal seas from 1957 to 2014 (Bakker et al., 2014)[3].
  Work at the University of Exeter is further utilitzing the SOCAT data product and neural network methodologies to develop comprehensive flux maps over seasonal, annual and decadal timescales of sea surface pCO_2 and air-sea CO_2 fluxes in/across the global ocean[4].

- ***Technology for GHG observations***
  Scientists and engineers at the National Oceanography Centre are working on technology development including platform and sensor development to improve CO_2 measurements in the surface ocean. C-enduro the autonomous surface vehicle (ASV) developed by NOC scientists in collaboration with industry partners is one type of technology being developed for such observational purposes.

[14] The UK has a strong GHG science community across marine, atmospheric and ecosystem sectors. These communities have formed a UK-ICOS committee (Appendix 1) and been working together over the past 9 months, to develop a common strategy to foster better UK engagement with ICOS-RI. The UK-ICOS committee has met 3 times, (twice in person and once remotely via video conferencing), demonstrating community enthusiasm for UK engagement in ICOS and better coordination of GHG research nationally. The most recent achievements of the UK-ICOS committee have been to ***shortlist stations for ICOS submission*** and start discussions over which observing stations will be full or associated ICOS stations (Appendix 2). ***These stations form the science contribution to ICOS-RI***.

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[3] Bakker, D. C. E. et al., (2014). "An update to the Surface Ocean CO2 Atlas (SOCAT version 2)." Earth Syst. Sci. Data 6(1): 69-90

[4] Landschützer, P., N. Gruber, D. C. E. Bakker, U. Schuster, S. Nakaoka, M. R. Payne, T. P. Sasse and J. Zeng (2013). "A neural network-based estimate of the seasonal to inter-annual variability of the Atlantic Ocean carbon sink." Biogeosciences 10(11): 7793-7815.

[15] The ***marine element of the UK observational component of ICOS*** is designed to capture both the air-sea exchanges and the oceanic sinks of GHGs. The coastal shelf seas around the UK are an important element of the NW European shelf (the latter being the most extensive coastal shelf sea globally). Furthermore, the North Atlantic, across which approximately half of the marine UK-ICOS stations are located is a major sink for anthropogenic CO_2.

[16] The marine observational strategy is built on a combination of Eulerian (fixed point) and Lagrangian (moving) stations to capture both the temporal and spatial variability in uptake. In the coastal zone, a long term station in the English Channel operated by PML (Western Channel Observatory) with over 25 years of data allows the ongoing uptake of GHGs by the shelf seas (and the associated impacts such as ocean acidification) to be monitored. This is complemented by CEFAS RV Endeavour ship based observations and the Smartbouy network. In the open ocean the principal observing systems are a combination of fixed-point open ocean observatories such as the Porcupine Abyssal Plain Sustained Observatory, and underway measurement systems collecting data on sea surface pCO_2 and air-sea CO_2 fluxes. These underway systems are fitted to both merchant vessels (e.g. the UK - Caribbean voluntary observing ships, operational as a science platform since 1995), and research vessels (e.g. the RRS James Clarke Ross which has operated as the principal vessel for a transect between the UK and Falklands/South America). Together these open ocean observational strategies allows the role of the North Atlantic in the global carbon cycle to be established.

[17] The ***atmospheric observing system of the UK component of ICOS*** is substantially built on the DECC tall tower network. This network is designed to allow the whole GHG budget of the UK to be established along with quantifying the impact of urban landscapes on this budget. The system operates in strong collaboration with a station on the west coast of Ireland at Mace Head and key UK atmospheric stations including Weybourne on the North Norfolk coast and Egham in suburban London. Furthermore the Meteorological Office station on the Channel Island of Jersey provides measurements of background air masses from the southwest, separating the UK from continental European emissions.

[18] The ***ecosystem observing system of the UK component of ICOS*** is designed to account for the heterogeneity present in UK landscape types and climate, reflecting the key ecosystems within the logistical constraints of having access to mains power. It aims to sample the uptake of carbon by forests, peatlands and grasslands, the major ecotypes with significant impacts on natural and anthropogenic GHG cycling.

[19] Alice Holt and Harwood Forest are two sites operated by the Forestry Commission, which typify the forested areas of the UK. Alice Holt in Hampshire is typical oak woodland, which across the UK contain 30% of broadleaved woodland carbon stocks. The measurements aim, which aims to quantify the inter-annual variation in carbon uptake and examine the effects of forest management on the partitioning of the carbon balance. Harwood Forest in Northumberland, is an upland Sitka spruce plantation which is the major timber production forest type in the UK and contains some 50% of conifer forest carbon stocks. The research site is aimed at understanding the effect of

management of such Sitka forest areas, often planted on organo-mineral soils, on the ecosystem whole GHG balance.

[20] Auchencorth Moss is a low-lying ombrotrophic peatland in SE Scotland, which boasts one of the longest CO_2 flux time series globally and is unique in quantifying also GHG losses from stream water export. The response of the year-to-year variation in net ecosystem exchange to climate drivers provides important information on the likely impacts of climate change on carbon accumulation in UK peatlands. Through Auchencorth Moss, a couple of small UK networks (the CEH Carbon Catchment Peatlands and the Defra Lowland Peatlands) will be referenced to ICOS.

[21] Crichton is a managed grassland site, with measurements operated jointly by Edinburgh University and SRUC (Scotland's Rural College). The site is used for both pasture and silage production and so represents a land cover typifying circa 30% of UK agricultural land. The site is maintained by SRUC and has a long history of research into grassland management. This site will provide not only intra and inter annual variation in trace gas emissions, but also crucial knowledge regarding management effects on these emissions.

[22] Despite not being a formal member to ICOS and therefore not in the position to report data to the ICOS Data centre, a number of UK scientists are already actively involved in the development of the measurement protocols for the ecosystems sites and presently the UK provides a co-chair for the Ecosystems Measurement Station Assembly.

6. Funding the UK contribution to ICOS

[19] In total, the UK contribution to ICOS can be broken down into the following constituent financial and non financial elements:

1. The ***physical observing systems*** (ICOS observing stations) identified for submission to ICOS-RI [14 - 21],
2. The ***operational costs*** to run the observing stations,
3. The ***capital investment*** in the infrastructure to establish and sustain the observing network and upgrade the requirements of ICOS where needed,
4. Financial support for the UK contribution to the ***Ocean Thematic Centre***,
5. The annual ***subscription fee*** to ICOS Head Office and ***station submission costs***.

[20] As discussed above [14 – 21] and outlined in Appendix 2, the ***physical observing system*** or ICOS observing stations ***(element 1 of the UK contribution to ICOS)***, which will constitute the UK's submission to ICOS-RI, has been identified. Full details of the activities of each station and its operational remit can be found in appendix 3.

[21] The ***operational costs (element 2 of the UK contribution to ICOS)*** to run the platforms, pay staff time and analyse the data is funded by a variety of different stakeholders (detailed in Appendix 3), including:

- ***DECC*** (supporting the tall towers network operated by Bristol University),

- ***Forestry Commission*** (supporting Forest Research and the associated terrestrial observing stations),
- ***Defra*** (supporting Cefas marine research activities),
- ***NERC*** (providing support at PML, CEH, NCAS and NOC via continuation of funding to Research Programmes such as the UK Greenhouse Gas and Shelf Sea Biogeochemistry and Discovery Science grants),
- ***Scottish government*** (supporting the activities of Marine Scotland Science)
- ***EU*** (through Framework Programmes and Horizon 2020 funding awarded to successful consortia of multiple Research Centres and Higher Education Institutions [HEIs])
- ***HEIs themselves*** (supporting staff time to work on projects)

[22] Given the breadth and scope of the observations made from the UK-ICOS platforms (as discussed in [14 - 21] and appendix 3) it is clear that the funding of operational costs provided by key stakeholders [21] ***facilitate a variety of observational needs*** that extend beyond the remit of ICOS. Overall the ICOS demands on the operational costs are a ***small fraction of the total effort*** invested into the stations. However, it should be noted that the ***length of funding is variable,*** (appendix 3) whilst ICOS requires a 5-year funding commitment. Typically NERC, Defra and DECC funding streams are reviewed on a sub 5 year cycle and are rarely coordinated in terms of the science across the marine, atmospheric and ecosystem sectors. EU funding is typically allocated for 3 – 4 years and is dependent on the funding calls at the time, thus is not necessarily a strategic programmatic investment.

[23] To ensure that the infrastructure is able to continue operating at a standard suitable for inclusion in the ICOS RI, ***capital investment in the UK infrastructure is needed (element 3 of the UK-ICOS system)***. To this end the UK-ICOS community has put in a request for capital investment to NERC, via the recent 2015 capital ideas call. This was a community approved request led by NOC, focusing on the technology need to ensure, scientific rigor of UK greenhouse gas data sets into the future and compliance with ICOS standards in the long term. However, this NERC ideas call currently has no guarantee of funding. Any calls for funding, based on the submitted ideas, would be allocated through an open and competitive process.

[24] Currently there are no direct funding streams allocated to support the activities of the ***UK contribution to the Ocean Thematic Centre (element 4 of the UK-ICOS system)***. To date, this work has been undertaken through in-kind contributions of the various institutions and HEIs. Currently, the agreement for the OTC is that member states hosting ICOS core functions will fund 80% of the operational costs. The remaining 20% will be funded through ICOS membership contributions. Much of the UK OTC work (summarized in [13]) is already being undertaken by the UK marine science community and would not be an additional workload. Secure funding streams for the necessary staff time to complete these actions needs to be identified.

[25] The final aspect of the UK-ICOS membership ***(element 5) is the annual subscription fee to the Head Office and station submission costs*** (appendix 4). Currently there is no identified funding stream for the cost of the ***annual subscription fee***, which allows members to receive the benefits of the thematic centre management, central calibration

services and the data portals (outlined in [9] above). Once paid, the country is a member of ICOS and may not withdraw membership within the first 5-year period. The ICOS General Assembly will consider only exceptional cases for withdrawal within the initial 5-year period, and in such cases a 12-month notice will apply.

[26] ***The station submission costs*** are dependent on the standard to which each individual station is categorized and the number of stations submitted (appendix 4). For a station to be included in the ICOS RI, funding must be secured over a 5-year timescale. Currently there is ***no identified funding stream*** for the cost of the ***annual station submission costs.*** If multiple centres, HEIs and/or other funders, invest in the annual UK-ICOS subscription costs it is likely that agreements will have to be drawn up between all partners before full engagement with the ERIC process can continue.

7. Strategic recommendations to MSCC

[27] Given the information laid out in this report discussing the scientific rationale, international and national, structure, organisation and implementation of ICOS, we draw the following conclusions:

- Individual funding streams allocated to observing programmes by DECC, Defra and NERC, are complementary to one another, and if appropriately coordinated can position the UK as a leading country within Europe for scientific excellence and capacity for GHG measurements.

- Not all components of the identified UK-ICOS stations are securely funded. This uncertainty places risk on the capacity of the UK community to deliver scientific excellence at the international level.

- The in-kind activities supporting the OTC are indicative of the level of engagement with ICOS, and the willingness of the science community to ensure that the UK remains at the forefront of scientific excellence. In the longer term such activities need to be grounded in secured funding streams, thereby ensuring that the strategic priorities of the national funding agencies complements the capabilities the science community.

[28] Given these conclusions we would like to make the following ***key recommendations to MSCC***:

1. To ***discuss the proposed membership of the UK to ICOS*** and determine if there is wider stakeholder backing for this activity.

2. To ***consider the complementarity of future funding programmes*** to ensure a more holistic delivery of world-class GHG observations and data products from the UK science community.

3. To ***examine the options to secure the funding for stations***, which are currently insecurely supported by HEIs and research programme funding (identified in

appendix 3), to enable their submission into ICOS-RI and to ensure a continuity of world class GHG observational capacity from the UK.

4. To ***consider future funding mechanisms to support the activities of the Ocean Thematic Centre***.

5. To ***consider funding mechanisms to support the cost of the annual subscription fee and annual station submission costs*** to the ICOS Head Office.

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Appendix 1: UK-ICOS committee members[5]

Name	Sector	Employer
Grant Forster	Atmosphere	UEA/NCAS
Tom Gardiner	Atmosphere	NPL
Alastair Manning	Atmosphere	MetOffice
Andrew Manning	Atmosphere	UEA
Stephan Matthiesen	Atmosphere (GHG programme manager)	University of Edinburgh
David Lowry	Atmosphere	Royal Holloway
Euan Nisbet	Atmosphere	Royal Holloway
Simon O'Doherty	Atmosphere	University of Bristol
Eiko Nemitz	Ecosystem	CEH
James Morisson	Ecosystem	Forest Research
Matt Wilkinson	Ecosystem	Forest Research
Dorothee Bakker	Marine	UEA
Anna Jones	Marine	BAS
Naomi Greenwood	Marine	CEFAS
Phil Nightingale	Marine	PML
Ute Schuster	Marine	University of Exeter
Richard Wood	Marine	Met Office
TBC[6]	(UK-ICOS project manager)	TBC
Richard Sanders	Marine (UK ICOS Stakeholder)	NOC
Andrew Watson	Marine (UK ICOS Focal Point)	University of Exeter

[5] The committee membership noted here should be seen as fluid rather than fixed. Participation is self-selecting rather than by nomination or appointment. People should represent their own, rather than institutional interests. The main remit of the committee is to produce documents, reports and have community sign off to show a concerted direction of travel for UK-ICOS activities, both now and into the future.

[6] To date Dr Riley has been project managing the UK-ICOS activities. As of the 4 September 2015 she changed jobs and the position is currently (as of the date of this report) vacant, with the view to it being filled in the immediate future. NOC are currently leading on this.

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Appendix 2: Proposed UK stations (July 2015)

Station Name[7]	Station sector (ocean, atmosphere, terrestrial)	Proposed station status
Porcupine Abyssal Plain Sustained Observatory	*Ocean*	Full
UK – Caribbean VOS line	*Ocean*	Full
Western Channel Observatory	*Ocean*	Full
James Clark Ross/AMT	*Ocean*	Associated
Warp SmartBuoy	*Ocean*	Associated
RV Cefas Endeavour	*Ocean*	Full
Marine Scotland[8]	*Ocean*	In discussion
Weybourne	*Atmosphere*	In discussion
Ridge Hill	*Atmosphere*	
Tacolneston	*Atmosphere*	
Angus	*Atmosphere*	
Bilsdale	*Atmosphere*	
RHUL, Egham	*Atmosphere*	
Jersey Meteorological Office	*Atmosphere*	
Divis	*Atmosphere*	
Alice Holt, Straits Inclosure	*Terrestrial*	Full
Auchencorth Moss	*Terrestrial*	Full
Crichton	*Terrestrial*	Full
Harwood Forest	*Terrestrial*	Full

[7] Note that the stations noted in the above table are the current iteration of the discussions. As such there may be some changes in which stations are submitted as full or associate members of ICOS. However, the UK-ICOS community anticipates that 4 stations from each sector will be submitted as full ICOS stations, with any remainder being associated stations.

[8] The contribution by Marine Scotland to the UK contribution to ICOS is currently being discussed

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Appendix 3: Detailed station information

MARINE STATIONS
Porcupine Abyssal Plain Sustained Observatory
Description **What:** Ocean mooring, with met office surface buoy **Location:** NW Atlantic, abyssal plain (49N, 16.5W) **Environment:** Open Ocean **Operational history:** 2002 - present **Scientific Purpose:** To understand how ocean and atmosphere processes regulate our climate and influence deep sea ecosystems using a eulerian approach **ICOS core parameters:** CO_2, pH, T, S, O2, NO_3, Chlorophyll, Wind speed & direction, Atmospheric pressure, Atmospheric temperature, sea surface pCO_2, sea surface temperature, sea surface oxygen, sea surface salinity, sea surface nutrients, sea surface chlorophyll, sea surface pH **Non ICOS parameters:** Particle flux, Zooplankton, Light, Benthic Biology **Funding:** Mostly NERC with EU top-up mainly for management costs. MetOffice funds some pieces of hardware. **Security of funding:** Funding to date has been continuous and is viewed as fairly secure **Funding end date:** No absolute end date but subject to regular review
UK – Caribbean VOS line
Description **What:** Voluntary Observing Ship, repeat line **Location:** UK – Caribbean 15 to 50 N and 72 to 0 W **Environment:** Open Ocean **Operational history:** 2002 - present **Scientific Purpose:** Seasonal to internannual variability of (i) sea surface pCO_2, (ii) air-sea CO_2 flux, and (iii) physical and biological drivers of the observed variability in the mid-latitude North Atlantic **ICOS core parameters:** CO_2 concentration, Wind speed & direction, Atmospheric pressure & temperature, Sea surface pCO_2, temperature, oxygen, salinity, nutrients **Non ICOS parameters:** **Funding:** NERC **Security of funding:** Short term project funding **Funding end date:** RAGNARoCC funding ending 2015
Western Channel Observatory
Description **What:** Mooring **Location**: English Channel, 50.25N, 4.21W **Environment:** Marine continental shelf, coastal waters **Operational history:** 1988 - present **Scientific Purpose:** The L4 and E1 sites in the western English Channel are long-term oceanographic time-series measuring a wide range of ecosystem and biogeochemical properties. These are brought together under the umbrella of the WCO to elucidate and disentangle environmental change. Recently an atmospheric observing station has been added at the mouth of the Plymouth Sound (Penlee Point) to observe fluxes of greenhouse and other trace gases. **ICOS core parameters:** CO_2 concentration, CH_4 concentration, N_2O concentration, nutrients, pH, DIC, TA, Wind speed & direction, Atmospheric pressure, Atmospheric temperature, Relative humidity, CO_2 flux **Non ICOS parameters:** Marine bio-geochemical measurements

Funding: NERC/EU/Other
Security of funding: NERC component via National Capability which will be reviewed in 2016
Funding end date: 2016

James Clark Ross/AMT

Description

What: Repeat ship section
Location: UK to Falklands/S. America, and Antarctic Ocean
Environment: Open ocean
Operational history: 1993 - preesnt
Wider context: Measurements of CO_2 in air and water + carbonate parameters on board the JCR. Measurements are made to quantify the air-sea flux of CO_2 and changes in the marine inorganic carbon system. The work also forms part of the Atlantic Meridional Transect (AMT), a basin-wide long-term multidisciplinary ocean observation programme.

ICOS core parameters: CO_2 concentration, CH_4 concentration, N_2O concentration (all in air and water), Wind speed & direction, Atmospheric pressure, Atmospheric temperature, Relative humidity, Water temperature, salinity
Non ICOS parameters: Marine bio-geochemical measurements

Funding: NERC/EU/Other
Security of funding: NERC component via National Capability which will be reviewed in 2016
Funding end date: 2016

Warp SmartBuoy

Description

What: Buoy
Location: North Sea 51.5235N 1.024E
Environment: Coastal marine
Operational history: 2000 - present
Wider context: A core component of the UK eutrophication monitoring programme. High frequency data are collected throughout the year for a range of chemical, physical and biological parameters for assessments of aquatic environmental status (e.g. under MSFD).

ICOS core parameters: Sea surface temperature & salinity, Nutrients (NO_3, NO_2, PO_4, SiO_4), DIC, TA, CO_2
Non ICOS parameters: Turbidity, chlorophyll, dissolved oxygen, phytplankton species composition and abundance

Funding: Defra
Security of funding: Under annual review
Funding end date:

RV Cefas Endeavour

Description

What: Research Vessel
Location: UK Shelf
Environment: Marine coastal waters
Operational history: 2009 - present
Wider context: Surface underway measurements of a range of chemical, physical and biological parameters for assessments of aquatic environmental status (e.g. under MSFD). Gives coverage of a large proportion of the UK shelf (at sea approx 300 days per year).

ICOS core parameters: Sea Surface pCO_2, Barometric pressure, Sea surface temperature, & salinity, Nutrients (NO_3, NO_2, PO_4, SiO_4), DIC, TA, wind speed and direction, humidity, air temperature
Non ICOS parameters: Turbidity, chlorophyll, dissolved oxygen, pH

Funding: Defra
Security of funding: Under annual review
Funding end date:

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ATMOSPHERIC STATIONS

Weybourne

Description

What: Coastal Station

Location: East Anglia coast, 52.95056 N 1.121944 E

Environment: Coastal, grassland, heathland, marshland and beach all close by.

Operational history: 1993 - present

Wider context: This station is used to make long term measurements of trace gases related to air quality and climate, in addition to mounting intensive campaigns to examine reactive tropospheric chemistry. Long-term measurements of O_3, CO, VOCs and NO_x began in 1993. CO_2 and O_2 and H_2 measurements began in 2008, with CH4 in 2013 and N2O and SF6 in 2014.

ICOS core parameters: CO_2, CH_4, N_2O, SF_6, CO, O2, wind speed and direction, temperature, pressure and relative humidity

Non ICOS parameters: H2, O_3, SO_2, CN and periodically VOCs, along with $^{13}CH_4$ analysis of bag samples

Funding: NCAS, UEA, NERC, EU

Security of funding: Long and short term funding

Funding end date: NCAS/UEA funding 31/03/2020

Ridge Hill

Description

What: Tall tower

Location: 51.997435N, -2.5399W

Environment:

Operational history: 2012 - present

Wider context: Measurement of CO_2, CH_4, N_2O and SF_6 to enable the determination of UK GHG emissions for DECC. The atmospheric derived inventory is compared to the National Inventory that is submitted to the UNFCCC.

ICOS core parameters: CO_2, CH_4, N_2O, SF_6

Non ICOS parameters:

Funding: DECC

Security of funding: 3 year tender

Funding end date: 2015

Tacolneston

Description

What: Tall Tower

Location: 52.51775N, 1.13872E

Environment:

Operational history: 2012 - present

Wider context: Measurement of CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs to enable the determination of UK GHG emissions for DECC. The atmospheric derived inventory is compared to the National Inventory that is submitted to the UNFCCC.

ICOS core parameters: CO_2, CH_4, N_2O, SF_6, CO, ^{13}C in CO_2, ^{18}O in CO_2, ^{14}C in CO_2

Non ICOS parameters: HFCs, PFCs, CFCs, Halons, Halocarbons, NMHCs, H2

Funding: DECC

Security of funding: short term

Funding end date: 2015

Angus

Description

What: Tall Tower

Location: 56.55511N, -2.98598W
Environment:
Operational history: 2005 - present
Wider context: Measurement of CO_2, CH_4, and CO to enable the determination of UK GHG emissions for DECC. The atmospheric derived inventory is compared to the National Inventory that is submitted to the UNFCCC.

ICOS core parameters: CO_2, CH_4, CO
Non ICOS parameters:

Funding: DECC
Security of funding: short term
Funding end date: 2015

Bilsdale

Description
What: Tall Tower
Location: 54.35858N, -1.15033W
Environment:
Operational history: 2014 - present
Wider context: Measurement of CO_2, CH_4, CO, N_2O and SF_6 to enable the determination of UK GHG emissions for GAUGE/DECC.

ICOS core parameters: CO_2, CH_4, N_2O, SF_6, CO
Non ICOS parameters:

Funding: NERC
Security of funding: short term
Funding end date: 2016

RHUL, Egham

Description
What:
Location: Surrey, 51.43°N, 0.56°W
Environment: Sub-urban
Operational history: 1995 - present
Wider context: Near-background Atlantic air from SW. London urban air from east. Understanding of urban greenhouse gas emissions and source attribution. Longest-running high precision UK mainland CO2 and CH4 station, and among the world's longest-running peri-urban high precision continuous (Picarro) measurement time series.

ICOS core parameters: CO_2, CH_4, N_2O, CO, ^{13}C in CO_2, Wind speed & direction, Atmospheric pressure & temperature, Radon-222
Non ICOS parameters: ^{13}C in CH_4

Funding: HEI (RHUL), NERC, EU
Security of funding:
Funding end date: EU funding - 2016

Jersey Meteorological Office

Description
What:
Location: Jersey, 49.18°N, 2.22°W
Environment: Coastal
Operational history: 2013 - present
Wider context: Atlantic background air from SW. Continental background air from S and SE. Can separate UK from continental emissions.

ICOS core parameters: CO_2, CH_4
Non ICOS parameters: ^{13}C in CH_4

Funding: EU (InGOS project)
Security of funding:
Funding end date: 2015

Divis

Description
What: Divis
Location: 54.607617°N 6.009235°W, Northern Ireland
Environment: Mountain, heathland
Operational history: 2013 - present
Wider context: the Divis site was set up as a demonstrator station for a potential commercial GHG monitoring and reporting service. However, its location, capabilities and operation have been organised in coordination with the wider UK tall tower network, with a particular emphasis on providing data for Northern Ireland - a gap in the wider network.

ICOS core parameters: CO_2, CH_4, CO, wind speed and direction, temperature, pressure and relative humidity
Non ICOS parameters: N_2O, SF_6, O_2, H_2, O_3, SO_2, CN and periodically VOCs, along with $^{13}CH_4$ analysis of bag samples

Funding: Commercial
Security of funding: Short-term, low security
Funding end date: 31/12/2015

ECOSYSTEM STATIONS

Alice Holt, Straits Inclosure

Description
What:
Location: Hampshire, 51.15353N, -0.85835E
Environment: Deciduous oak forest
Operational history: 1999 - present
Wider context: Quantification of carbon, water vapour and energy fluxes from a deciduous oak woodland in south-east England using eddy co-variance. Through integration with other research programmes, long-trem monitoring and external collaborators, the main aims of the site are to quantify inter-annual variation in carbon uptake, examine the effects of management and to understand the partitioning of the carbon balance.

ICOS core parameters: CO_2, H_2O and sensible heat fluxes (eddy covariance), Air CO_2 and H_2O vertical profile, In, Out and Net SW and LW radiation, PAR/PPFD incident, Diffuse PAR/PPFD radiation, Soil Heat flux, Air Temperature and Rh profile, Main meteo vars (Ta, Rh, Swin, precipitation), Total high accuracy, precipitation, Rain precipitation, Soil Water Content profile, Soil Temperature profile, Tree diameter, Phenology-Camera, Wind speed and wind direction (additional), LAI, Litterfall
Non ICOS parameters: Environmental monitoring according to ECN protocols, Environmental monitoring according to ICP Forest protocols, UK COSMOS site

Funding: Forestry Commission
Security of funding: Subject to DEFRA spending review
Funding end date: FC funding until March 2019

Auchencorth Moss

Description
What: Ecosystem flux station co-located with air quality supersite
Location: South East Scotland
Environment: Peatland, patchy mix of grasses and sedges covering a *Sphagnum* base layer on a typical peatland hummock/hollow microtopography.
Operational history: Net Ecosystem Exchange measurements since 2002
Wider context: Serves multiple networks, including: EMEP Air Quality network, WMO Regional Site status, CEH Carbon Catchments, former EU projects Carbomont, NitroEurope, ECLAIRE; has been reporting CO_2 fluxes to the European Flux Database (www.europe-

fluxdata.eu) since 2002.

ICOS core parameters: : NEE (closed-path IRGA), air and soil temperature, Rainfall, Phenocam, Radiation (total solar, PAR, net radiation), Water table depth, , EC flux of CH_4 (at times), plant & soil analyses (depending on project funding); measurements do not currently comply with ICOS standards (some of which are still being finalised)
Non ICOS parameters: EMEP air quality supersite (Level-2/3) (> 300 air quality parameters such as concentrations of O3, NO, NOx, many VOCs, aerosol chemical composition, aerosol size distribution, N and S gases, POPs mercury etc.); WMO GAW regional sites; serves numerous national Defra networks; Fluxes of NH_3, NO_x, SO_2, VOCs, O_3, soil chambers for CH_4, N_2O, NO – depending on project funding, currently fluxes of O_3 ongoing; DIC/DOC in stream water outflow + CO_2 loss to atmosphere.

Funding: Mainly Defra and NERC NC, with funding from ACTRIS and other funding (EU & NERC RM)
Security of funding: Subject to Defra spending review and transition to new NERC NC model, but highly likely to be continued to funded at some level
Funding end date: Defra contract will be up for renegotiation Dec-2016; to date NC funding had to be applied for every financial year, but will hopefully migrate onto a longer-term funding rotation

Crichton

Description
What: managed grassland
Location: Dumfries (55° 2'32.54"N, 3°35'2.71"W)
Environment: Managed grassland for hay cropping and grazing of a dairy herd. Maritime temperate climate**.** Topographic slope of ~2.5° with a south-westerly aspect.
Operational history: Eddy covariance fluxes since 2014, chambers since 2013, management history since 1975
Wider context Managed grasslands, such as this site, account for a third of UK agricultural land cover. Selection of the Crichton site builds on existing agriculturally based research at this site by SRUC going back many decades. Joint management of Crichton will strengthen cooperative ties between SRUC and Edinburgh University. This site also provides an opportunity to monitor processes of three major trace gas (CO_2, CH_4, N_2O) processes, all of which have been observed to be active this single site.

ICOS core parameters: Fluxes: CO2, H2O & sensible heat (eddy covariance) at 2.5 m and 11 m. Radiation: 4-component net radiometer at 9 m, diffuse/direct/incident/reflected PAR. Hydrology: Rain Gauge, Wetness, Soil moisture probes (6 in each soil pit). Soil: Temperature (6 in each soil pit), Soil heat flux (1 in each soil pit). Atmospheric: Barometric pressure, air temperature, relative humidity, CO/CH4 concentration, wind speed and direction. Soil physical hydrological and chemical properties.
Non ICOS parameters: UK COSMOS site (soil moisture), soil chambers for CH_4, N_2O, NO – depending on project funding, Spatial distributed eddy covariance fluxes of CO2, H2O & sensible heat – depending on project funding. Field scale sampling grid of topography, soil moisture, canopy properties.

Funding: SRUC & (NERC) GREENHOUSE Project
Security of funding: unknown
Funding end date: NERC funding until end 2016

Harwood Forest

Description
What: Forest Tower (32m)
Location: Harwood Forest, Northumberland,
Environment: Upland Sitka spruce forest
Operational history: 2013 – present (previous research has been carried out by University of Edinburgh)
Wider context: Upland Sitka spruce (*Picea sitchensis* L.) plantations are one of the major forest types in the UK, producing valuable timber products and also helping remove carbon from the atmosphere. Their management is therefore important in improving their greenhouse gas (GHG) balance. The main aims of the site are to quantify the carbon and GHG balance at different points in the forest management cycle by comparing a mature stand with a recently clearfelled area.

ICOS core parameters: CO_2, H_2O & sensible heat fluxes (eddy covariance), air CO_2 & H_2O vertical profile, in, out and net SW and LW radiation, PAR/PPFD incident, diffuse PAR/PPFD radiation, soil heat flux, air temperature and RH profile. Main meteo variables , Swin, precipitation, soil water content profile, soil temperature profile, tree diameter, phenology-camera, wind speed and wind direction, LAI & Litterfall
Non ICOS parameters: UK COSMOS site

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Funding: Forestry Commission & (NERC) GREENHOUSE Project
Security of funding: Forestry Commission funding subject to DEFRA spending review
Funding end date: FC funding until March 2019, NERC funding until 2016

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Appendix 4: Subscription costs for ICOS membership

Total subscription fees are composed of the annual subscription fee to the ICOS central office and the annual station cost. The estimated total cost assuming all stations (listed in Appendix 2) is submitted at the highest station level and annual membership costs is in the region of £130,000/year.

Average annual predicted membership costs 2014 - 2018		**Cost €**	**~ Cost £**
Subscription Fee to ICOS central office (One fee per annum per member state)	**Common Basic Contribution** (Sharing 50% of the common costs between members)	€16,144.80	£11,267.82
	Common Gross National Income Based Contribution (Sharing 50% of the common costs as follows 3 year aggregated GNI (from EUROSTAT) expressed as a % of all members & observers)	€32516.60	£22,694.08
Total Average Subscription Fee Costs (Payable to ICOS central office)		**€56,411.40**	**£39,371.90**

***Annual Station Contributions** (A per station cost which will vary dependent sector and station classification)		**Cost €**	**~ Cost £**
Ecosystem[9]	**C1**	€6,000.00	£4,187.54
	C2	€3,000.00	£2,093.77
	Associated	€1,500.00	£1,046.88
Atmosphere[6]	**C1**	€9,500.00	£6,630.27
	C2	€7,500.00	£5,234.42
Ocean[10]	**C1**	€7,500.00	£5,234.42

[9] Station contributions for Ecosystem and Atmospheric Stations are subdivided into Class 1 and Class 2. These classes will differ in the completeness of the measurements supported. This strategy aims to enhance flexibility in including stations into the network. The ecosystem sector also has an associated station classification.
Associated stations will be required to submit a full year of data, including key variables, full metadata and be compliant with ICOS data policy to maintain the ICOS Associate Status.
Any station classed as associated is not part of the ICOS network, but will be included in the ICOS database.

[10] There is currently only one standard of station submission for the marine sector.