# ICOS SWEDEN Annual Report 2020

ICOS National Network Sweden

Lunds Universitet · Göteborgs Universitet · Uppsala Universitet · SLU · Polarforskningssekretariatet · SMHI · Swedish Research Council

*The Board of ICOS Sweden endorsed this Annual Report 2020 on 11 March 2021. The report is complemented by other documents from ICOS Sweden, including the Operational Plan for 2021, the Strategic plan 2021-2024, and the ICOS Sweden user statistics for 2020.*

# Innehåll

# 1. Introduction to ICOS Sweden

ICOS - Integrated Carbon Observation System - is a European research infrastructure for quantifying and understanding the greenhouse gas balance of the European continent and of adjacent regions. The infrastructure is built up as a collaboration of nationally operated measurement stations in, at present, 14 European countries. ICOS Sweden is the Swedish contribution to this European effort. An ERIC (European Research Infrastructure Consortium) 'ICOS ERIC' has been established as a legal entity for ICOS data release as well as the coordination and integration of the whole research and measurement infrastructure, ICOS Research Infrastructure (RI), that includes the national networks, the measurement station assemblies and the central facilities (Fig. 1).

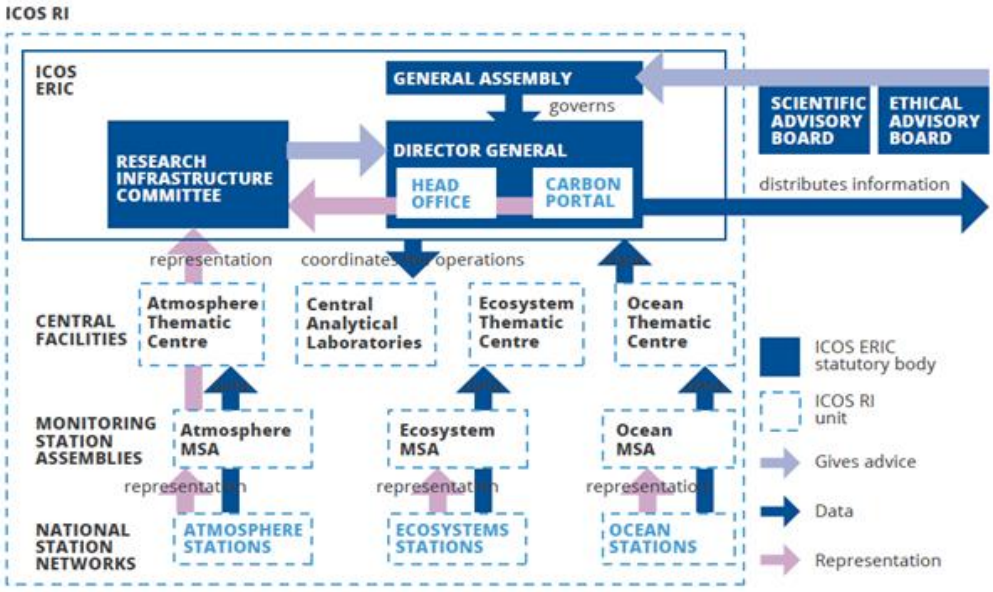


***Figure 1.*** *Outline of the ICOS RI organization. Sweden is a member of ICOS ERIC and ICOS Sweden is the Swedish node.*

High-precision, standardized observations of the exchange of greenhouse gases and heat between the Earth's surface and its atmosphere form an essential basis for understanding not only our planet's present climate, but also past and future developments. It has also become clear that these studies must be secured beyond the lifetime of a typical research project. The aim of ICOS is therefore to construct, equip, and operate a network of standardized, long-term, high precision integrated monitoring stations for atmospheric greenhouse gas concentrations and fluxes. At the moment, the ICOS Research Infrastructure has more than 100 stations in 14 European countries. The current ICOS Atmosphere and Ecosystem Networks include more than 30 atmospheric and around 70 ecosystem stations located across Europe. The ICOS Ocean Network covers the North Atlantic and European marginal seas. The Ocean Observation System will consist of more than 20 facilities: Voluntary Observatory Ships, so called Ships of Opportunity (SOOP), fixed stations and research vessels.

ICOS Sweden is fully integrated with and plays an important role in the pan-European ICOS (ICOS RI). ICOS Sweden has been providing data, and that help to compile information on greenhouse gas exchange of typical northern ecosystems to the research community as well as Swedish stakeholders. ICOS Sweden will furthermore provide test sites for national inventory systems and sites and databases for advanced research.

ICOS RI stations are separated into 3 different classifications:

- **Class 1 station:** ICOS Ecosystem or Atmosphere Station with a complete equipment setup for measuring the full set of ICOS core variables.
- **Class 2 station:** ICOS Ecosystem or Atmosphere Station with a complete equipment setup for measuring ICOS core variables. Less variables are measured compared to the Class 1 station and ancillary data are determined less frequently.
- **Associated station:** The network of ecosystem sites in ICOS is enlarged to a set of Associated stations where the requirements in terms of variables collected and standards to follow are different from the Class 1 and Class 2 ICOS stations. Ecosystem fluxes calculated by the station principal investigator and data at final time resolution are submitted to the Thematic Center.

## 2. Status of ICOS Sweden at the end of 2020

ICOS Sweden makes measurements from stations distributed across Sweden, from Abisko-Stordalen in the north to Hyltemossa in the south (Fig. 2). During the current funding period, there are three Atmosphere stations (AS) for measurement of concentrations of GHGs in the well-mixed boundary-layer, six Ecosystem stations (ES) for measurements of exchanges of GHGs between ecosystems and the atmosphere, and one Ocean station (OS) for observations of the coastal Baltic Sea.

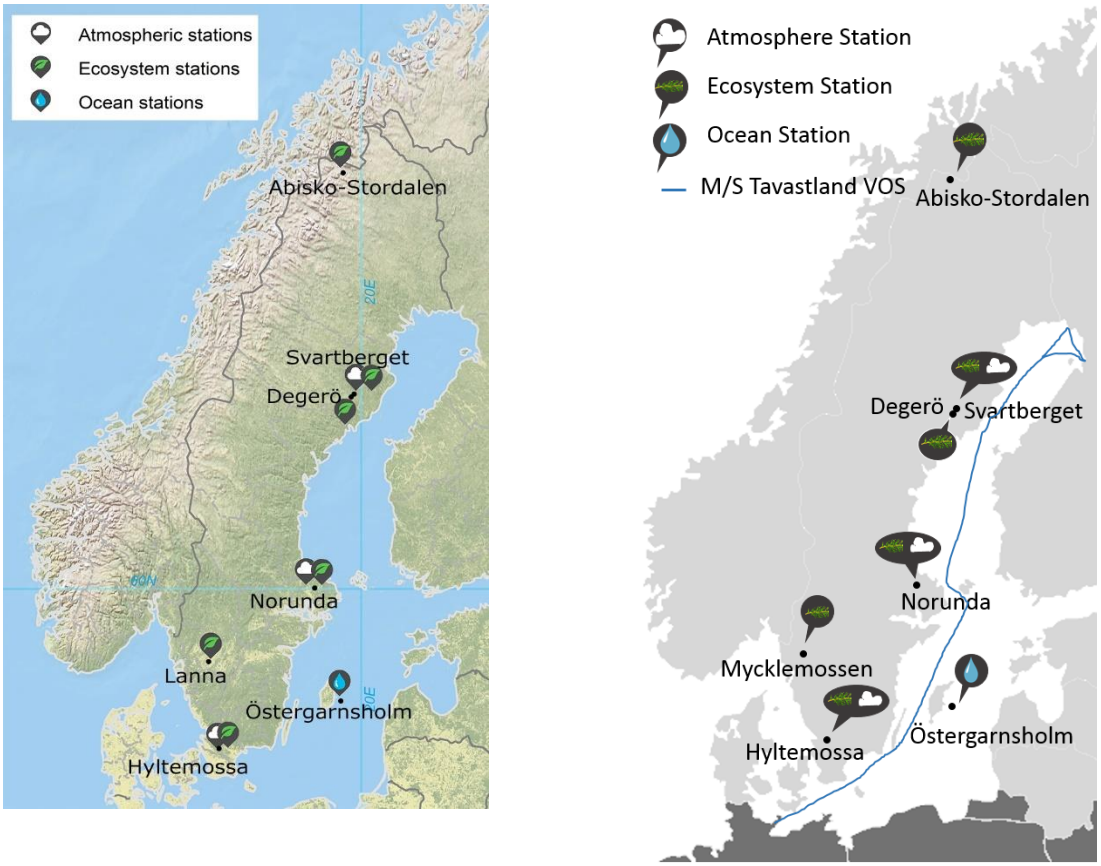


***Figure 2.*** *Map with the ICOS Sweden stations; left: before 2020, right: from 2021. The stations represent the different climate zones found in Sweden. They are unique stations in the continental scale of ICOS RI.*

The stations are run by the consortium partners Lund University, University of Gothenburg, Swedish University of Agricultural Sciences, Uppsala University, Swedish Meteorological and Hydrological Institute, and The Swedish Polar Research Secretariat. The framing of the cooperation is set by a formal agreement.

**Lund University (LU)** is the host organization with overall responsibility for the coordination of ICOS Sweden, and for the operations of four ICOS stations: the Norunda forest Ecosystem and Atmosphere stations, and the Hyltemossa forest Ecosystem and Atmosphere stations.

**Swedish University of Agricultural Sciences (SLU)** operates three ICOS stations: Svartberget forest Ecosystem and Atmosphere stations, and the Degerö mire Ecosystem station.

**University of Gothenburg (UGOT)** has been responsible for the operations at the agricultural Lanna Ecosystem station which has been closed down; from 2021 GU will be responsible for the ICOS measurements at the mire Ecosystem station Mycklemossen.

**Uppsala University (UU)** operates the Östergarnsholm Ocean station.

**Polar Research Secretariat (PFS)** runs the Abisko-Stordalen mire Ecosystem station.

**Swedish Meteorological and Hydrological Institute (SMHI)** operates the Ocean station measurements onboard the Ship of Opportunity (SOOP) M/S Tavastland.

The status of all measurement stations at the end of 2020 is summarized in Fig. 3. ICOS Sweden became, for most of the measurement systems, operational during 2014. In 2016, the labeling process procedures and the criteria for the different types of stations were specified by ICOS RI. In spring 2018, all three atmospheric stations (Svartberget, Norunda, Hyltemossa) were certified as Class 1 ICOS RI Atmosphere stations. Measurements and calibrations following the Atmosphere Thematic Centre's (ATC's) and the Central Calibration Facility's (CAL's) schedules are ongoing; data is transferred automatically to the ATC each night. The flask sampling system is not yet fully operable at all sites due to delays from the developer's side. The last final measurement data release by the ATC including data from ICOS Sweden stations was in July 2019. These data as well as near real time data from the atmospheric stations are now available for users via access through the Carbon Portal[1].

The three forest Ecosystem stations Hyltemossa, Norunda and Svartberget achieved the ICOS RI label as Class 2 Ecosystem station. The mire site Degerö received the label in November 2019. Measurements (manual for ancillary vegetation data and automatic data sampling) are ongoing following the instructions of the Ecosystem Thematic Centre (ETC), which are based on the elaborated protocols for Ecosystem station measurements[2] and data is automatically transferred to the ETC via the Carbon Portal each night. The labeling process of Abisko-Stordalen and Lanna was hold by ICOS Sweden to wait for the outcome of the application for the coming funding period. Östergarnsholm is expected to become certified by ICOS RI in 2020; changes in the OTC protocols in 2019 delayed the original plan of receiving the label in 2019.

[1] https://data.icos-cp.eu/portal

[2] www.international-agrophysics.org/infopage/articles/y/2018/pub/1/issue/4

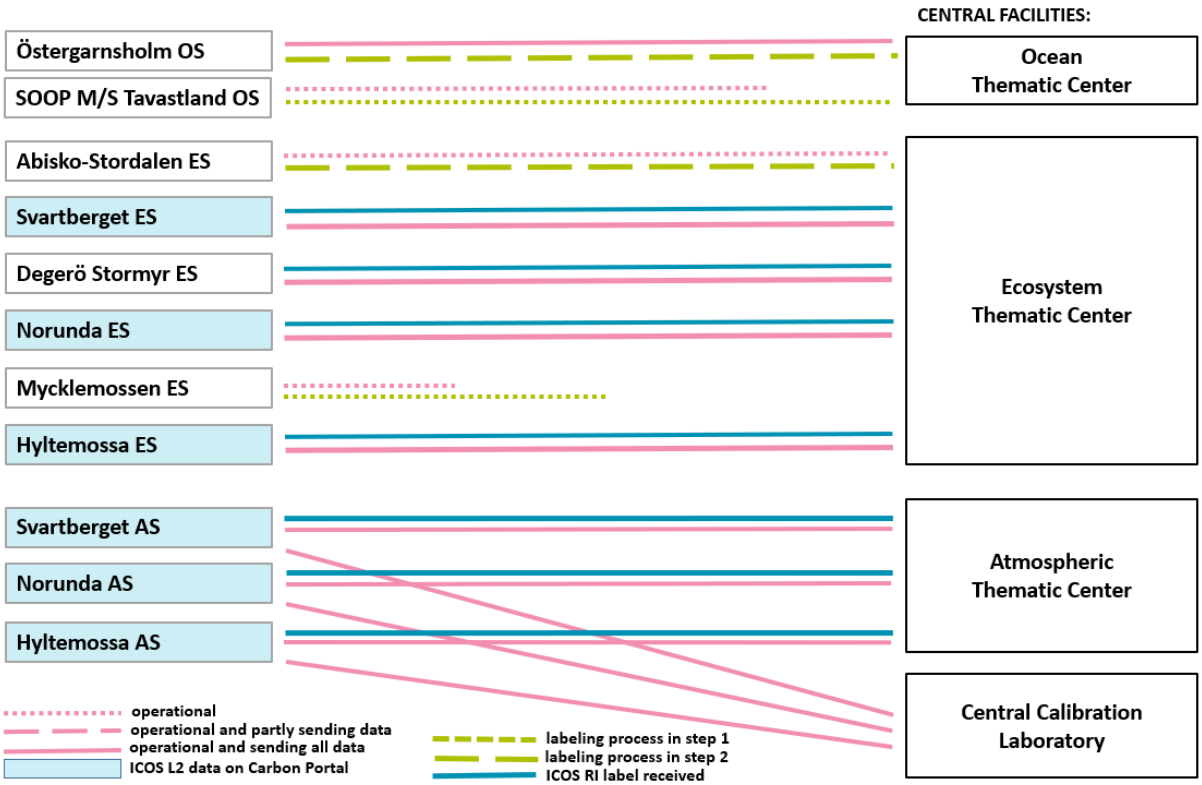


***Figure 3.*** *The development status for the delivery of data and information from the ICOS Sweden measurement stations to the ICOS Central Facilities (October 2020). Blue lines – development status for data delivery. Green lines – status ICOS labeling. AS – Atmosphere station, ES – Ecosystem station, OS – Ocean station.*

### *ICOS Sweden data*

Most data from the ICOS Sweden ecosystem network (start 2014, resp. 2015) has been available and searchable as ICOS Sweden data on the ICOS ERIC Carbon Portal. ICOS Sweden is continuously working on updating the files in the repository. The exact status of the data is summarized in Table 1. Furthermore, ICOS Sweden contributed to the data collections for the analyses of the Drought 2018 and the Warm Winter 2019/20, resp. consequences of the shutdown due to the covid-19 pandemic. Data from these initiatives is (Drought 2018), resp. will be (Winter 2019/20-Covid19) available through the ICOS ERIC Carbon Portal.

***Table 1.*** *Status of ICOS Sweden data products on the Carbon Portal on 2021-02-26.*

| | Fluxes (annual files) | Meteo variables (annual files) | Gas and temperature profile variables (annual files) | Eco variables (annual files) | Metadata on instruments and variables |
|---|---|---|---|---|---|
| SE-Htm | 2015-2020 | 2015-2020 | 2015-09/2020 | 2015-2020 | On landing page at CP (variables and heights), resp on icos-Sweden.se |
| SE-Lnn | 2014-2019 | 2014-2019 | -- | 2014-2018 | On landing page at CP (variables and heights), resp on icos-Sweden.se |
| SE-Nor | 2014-2020 | 2014-2020 | | 2014-2020 | On landing page at CP (variables and heights), resp on icos-Sweden.se |
| SE-Deg | 2014-2019 | 2014-2019 | -- | 2014-2019 | On landing page at CP (variables and heights), resp on icos-Sweden.se |
| SE-Svb | 2014-2020 (not: 2017) | 2014-2020 | 2014-07/2020 (not: 2018) | 2014-2020 | On landing page at CP (variables and heights), resp on icos-Sweden.se |
| SE-Sto | 2014-2019 | -- | -- | 2014-2019 | On landing page at CP (variables and partly heights), resp on icos-Sweden.se |

# 3. Highlights in science and management during 2020

## 3.1 Management

- The start-up of the 3rd funding period of ICOS Sweden (ICOS SE 3.0) was finalized in 2020 including the contract with VR and the update of the consortium agreement which formally defines the rights and obligations between the partners. For this, the initially proposed budget and strategy needed to be revised and adjusted to the granted funding situation. The consortium agreement is based on the result of an investigations of the ICOS Sweden management structure which was initiated by the rector of Lund University and the Faculty of Science in summer 2020.

- The phd course "From $CO_2$ in situ measurements to carbon balance maps as a tool to support national carbon accounting" run by the Department of Physical Geography and Ecosystem Science at LU got large input from ICOS Carbon Portal and ICOS Sweden. The course was supported by ClimBEco and was included in the ClimBEco research school course program (CEC, Lund University, Sweden). The course aimed at introducing the concept of assessing the carbon balance of a geographical region from in situ measurements and how the results can be used as a tool to support national carbon accounting.

- In late spring 2020 the project application 'ICOS – resource for school' was approved by the SRC. The aim of the project is to stimulate interest of children at high school age in STEM subjects. This will be done by creating programming exercises using ICOS data as well as description videos and texts within the ICOS measurement context related to multiple topics of the school curriculum. The project is done in collaboration with the Swedish Science Centers.
- To meet new security standards, a new website was migrated into the ICOS ERIC Carbon Portal hosted Drupal system. At the end of 2020, the new website was finally released; it is available at the same web address www.icos-sweden.se as before.

- Janne Rinne, who has been SPI at Abisko-Stordalen has been acting as chair of the Ecosystem MSA. This is an important leadership link between ICOS Sweden and ICOS RI.

- To make sure that the maintenance at the measurement stations could be continued during the covid-19 pandemic, risk assessments were updated regularly, and support letters signed by the ICOS Steering Group were send to the partner universities and institutions.

- The ICOS Sweden management team supported by the steering committee engaged in being involved in the European Green Deal. The ICOS RI community handed in a proposal (PAUL: "Pilot Application in Urban Landscapes towards integrated city observatories for greenhouse gases") on the extension of the Carbon monitoring to urban surroundings. During the preparation of the proposal, several cities handed in their interest of being selected as pilot study. ICOS Sweden supported ICOS Denmark with the suggestion Copenhagen, which would have been in line between Danish ICOS stations and Hyltemossa on the Swedish side of the Öresund. For the proposal, Munich was chosen as main pilot city, Zurich and Paris are second tier.

## 3.2 Measurement stations

### 3.2.1 Station certification

All three certified Atmosphere stations delivered data for the mandatory variables to the Atmospheric Thematic Center throughout 2020; the certified Ecosystem stations delivered data for the mandatory variables to the Ecosystem Thematic Center throughout 2020. The mire Ecosystem station Mycklemossen entered the first step of the labeling procedure. For SOOP M/S Tavastland, the first step of the labeling process was approved by the OTC. The fixed Ocean station Östergarnsholm is in the second step of labeling; additional measurements for validation requested by OTC will be collected in spring 2021.

### 3.2.2 Station highlights

At the stations, the maintenance work to ensure high quality, continuous data had high priority. Following the Swedish Government's and Public Health Authority's recommendations regarding measures to reduce the spread of the coronavirus (Covid-19), risk assessments and detailed workplace strategies have been set up. Study visits from courses have been mainly transferred to digital visits as far as possible, especially in the second half of the year. Visits by master students and interns to the stations have been very restricted. At most stations, however, despite the restrictions, users could come and perform their fieldwork. E.g. at Svartberget, SLU Uppsala started measurements on soil $CO_2$ concentration using miniature autonomous $CO_2$ sensors (Senseair). The measurements should continue during the next years and will be compared to the ICOS Sweden below canopy gas measurements. Hyltemossa is part of a new infrastructure project related to ACTRIS and ICOS, which got funded through the European Commission INFRAIA-03-2020 call. ATMO-ACCESS is the organized response of distributed atmospheric research facilities ACTRIS, ICOS, and IAGOS for developing a pilot for a new model of Integrating Activities. The project will deliver a series of recommendations for establishing a comprehensive and sustainable framework for access to distributed atmospheric Research Infrastructures (RI), ensuring integrated access to and optimised use of the services they provide.

Since SOOP M/S Tavastland is operating between Finland and Germany, it has been not possible for Swedish citizens to get access for maintenance of the scientific equipment since early 2020. To ensure the continuation of the measurements despite these difficulties, SMHI gets help by the Geomar (Germany) for maintenance work at the $pCO_2$ system and by EHP Environmental (Finland) for maintenance work related to the ferrybox. Thanks to this, measurements could be carried out throughout 2020 except for a two-week period in February when the ship was out of service due to a strike.

## 3.3 Dissemination

### 3.3.1 Conferences and Meetings

In March 2020, the final meeting of the EU funded project RINGO (Readiness of ICOS for Necessities of Integrated Global Observations) took place in Poznan, Poland, with participation of ICOS Sweden researchers. SPIs and station team members took actively part in the MSA meetings of all three domains, Atmosphere, Ecosystem and Ocean which were held online during 2020 due to covid-19 pandemic restrictions.

Also due to the pandemic, most conferences during 2020 were held online, giving the chance for a more researchers to be part in international conferences like EGU or the ICOS Science Conference. Data from the ICOS Sweden stations were subject of several presentations at the conferences.

### 3.3.2 Joint data initiatives

ICOS Sweden actively contributed to the European wide Drought Force which was initiated by ICOS RI. The special issue with 17 articles on the hot and dry year 2018 was released in Philosophical Transactions of the Royal Society B (https://royalsocietypublishing.org/toc/rstb/375/1810). Scientists involved in ICOS Sweden actively took part or even took the lead in the writing of publications on the effects of the 2018 drought on ecosystems in the north. This resulted in six papers authored or co-authored by researchers in Swedish institutions with two first author papers focusing on forests (Lindroth et al, 2020) and mires (Rinne et al., 2020) in the north. Parts of Europe and the Nordic region was exposed to severe drought and high temperature during the 2018 growing season. Lindroth et al. (2020) compared the effects of the drought on the carbon and water fluxes by analysing eddy-covariance flux data from eleven forested ecosystems in northern Europe (Estonia, Finland, Sweden, and Denmark). The drought had the longest duration in the southern part, but it was still severe in the northern part of the region. Evapotranspiration was unchanged or even increased at most sites. Only two sites showed slightly reduced evapotranspiration. The effect on annual net ecosystem productivity varied considerably between the eleven forests included in the study. Eight out of the eleven forests still acted as annual C sinks. In six out of eleven forests, the annual net ecosystem productivity was reduced by more than 50 g C $m^{-2}$ $yr^{-1}$. In one forest, the net uptake was reduced by as much as 389 g C $m^{-2}$ $yr^{-1}$. Two of the forests in the north benefited from the favourable weather conditions (i.e., increased $T_{air}$) during the drought and increased their net uptake. Rinne et al. (2020) analysed the effects of the drought on five mire ecosystems in northern Europe (Finland and Sweden). The lowered water table depths at the sites lowered both carbon dioxide ($CO_2$) uptake and methane ($CH_4$) emission during 2018, turning three out of the five mires from $CO_2$ sinks to sources. The calculated radiative forcing showed that the drought-induced changes in GHG fluxes first resulted in a cooling effect lasting 15–50 years, due to the lowered $CH_4$ emission, which was followed by warming due to the lower $CO_2$ uptake.

A similar joint data effort was started in 2020 with the focus on the mild weather conditions during winter 2019/2020 and possible effects of the covid-19 shutdown in early 2020. As for the drought data, PI processed data (fluxes and meteorological data) from most ICOS Sweden ecosystem stations was submitted to the Ecosystem Thematic Center for gap-filling and release on the ICOS ERIC Carbon Portal. Atmosphere station data is available as ICOS data on the Carbon Portal.

# 4. References


- Lindroth, A., Holst, J., Linderson, M.L., Aurela, M., Biermann, T., Heliasz, M., Chi, J., Ibrom, A., Kolari, P., Klemedtsson, L., and others (2020). Effects of drought and meteorological forcing on carbon and water fluxes in Nordic forests during the dry summer of 2018. Philosophical Transactions of the Royal Society B, 375(1810), p.20190516.
- Rinne, J., Tuovinen, J.P., Klemedtsson, L., Aurela, M., Holst, J., Lohila, A., Weslien, P., Vestin, P., Łakomiec, P., Peichl, M., and others (2020). Effect of the 2018 European drought on methane and carbon dioxide exchange of northern mire ecosystems. Philosophical Transactions of the Royal Society B, 375(1810), p.20190517.


# 5. Financial outcomes 2020

A summary of the financial outcomes for 2020 for all sites are given in Table 2 below. Costs at the stations were higher in 2020 as in previous years. At LU stations, e.g., extra student help was needed

for the time-consuming mandatory soil sampling. Also, investments for completing the measurement systems (flasks for automatic flask sampler, data loggers, spare instruments for all stations) at the sites were made. However, the drift costs at LU were remarkably lower than during previous years, due to the reduction of travelling in connection to covid-19 pandemic restrictions. At SLU higher personal costs were due to extra staff to complete mandatory time-consuming inventory tasks. The deficit for 2020 is covered by surpluses from the previous years.

***Table 2.*** *Financial outcomes 2020 for each partner and in total (kSEK). For acronyms, see Appendix 3.*

| | LU | SLU | GU | UU | PFS | TOTAL |
|---|---|---|---|---|---|---|
| ***Incomes*** | | | | | | |
| Incomes SRC | *3146* | *2114* | *970* | *770* | *0* | *7000* |
| Co-financing | *4471* | *3330* | *1309* | *1301* | *580* | *10991* |
| **Sum** | ***7617*** | ***5444*** | ***2279*** | ***2071*** | ***580*** | ***17991*** |
| | | | | | | |
| ***Costs*** | | | | | | |
| Salaries | *4264* | *5384* | *1027* | *1804* | *396* | *12875* |
| Consumables incl travels | *1206* | *1670* | *255* | *826* | *75* | *4032* |
| OH | *2090* | *908* | *599* | *667* | *109* | *4373* |
| Technical Support | *514* | *449* | *193* | *128* | *0* | *1284* |
| Investments | *1342* | *300* | *0* | *208* | *0* | *1850* |
| **Sum** | ***9416*** | ***8711*** | ***2074*** | ***3633*** | ***580*** | ***24414*** |
| | | | | | | |
| **Difference** | ***-1799*** | ***-3267*** | ***205*** | ***-1562*** | ***0*** | ***-6423*** |

# Appendices

# Appendix 1: List of personnel during 2020

## *Total amount of FTEs: 14.5*

### Coordination Office:

Maj-Lena Linderson, coordinating director, 50%
Janne Rinne, science director and ICOS Sweden SE for Lund University, 20%
Jutta Holst, scientific secretary 20%, scientific and technical station support, 80%
Meelis Mölder, scientific and technical station support, 70%
Yvonne Kedström, secretary, 5%

### Measurement stations:

**Abisko-Stordalen:**
50% split into research engineers Erik Lundin,
Alexander Meire, and Niklas Rakos
Janne Rinne, station PI and SE, 10%

**Degerö and Svartberget:**
Mikaell Ottosson Löfvenius, research engineer, 25%
Paul Smith, AS station PI, research engineer, 100%
Pernilla Löfvenius, Experiment Technician, 25%
Guiseppe de Simon, research engineer, 50% (parental leave)
Rowan Dignam, Research Engineer, 100%
Tommy Andersson, research engineer, 66%
Per Marklund, research engineer, 100%
Hassan Ridha, Auxiliary Experiment Assistant, 50%
Mats Nilsson, ES station PI and SE, 10%
Matthias Peichl, ES station PI, 10%

### Norunda:

Irene Lehner, research engineer, 100%
Anders Båth, research engineer, 90%
Meelis Mölder, station PI, research engineer, 30%
Natascha Kljun, SE

### Östergarnsholm:

Anna Rutgersson, station PI and SE, 35%
Marcus Wallin, research engineer, 50% (Jan-Mar)
Leonie Esters, research engineer, 50% (Apr-Dec)
Erik Nilsson, research engineer, 45%
Hans Bergström, research engineer, 5%

### Lanna/Mycklemossen:

Per Weslien, station PI, research engineer, 75%
Bengt Liljeblad, research engineer, 25%
Leif Klemedtsson, SE, 20%

### Hyltemossa:

Tobias Biermann, research engineer, 100%
Michal Heliasz, station PI, research engineer, 100%
Thomas Holst, research engineer, 20%

# Appendix 2: List of measurement variables and instruments/systems

## Table 2.1 ICOS Sweden Ecosystem station parameters

| **Ecosystem stations** | | **Hyltemossa (SE-Htm)** | **Norunda (SE-Nor)** | **Svartberget (SE-Svb)** | **Lanna (SE-Lnn)** | **Degerö (SE-Deg)** | **Abisko-Stordalen (SE-Sto)** |
|---|---|---|---|---|---|---|---|
| Scientific PI | | Michal Heliasz, LU | Meelis Mölder, LU | Matthias Peichl, SLU | Per Weslien, UGOT | Mats Nilsson, SLU | Janne Rinne, LU |
| ecosystem type | | forest | forest | forest | agricultural | mire | palsa mire |
| Latitude | | 56°06'N | 60°05'N | 64°10'N | 58°20'N | 64°11'N | 68°21'N |
| Longitude | | 13°25'E | 17°29'E | 19°47'E | 12°06'E | 19°33'E | 19°03'E |
| Height a.s.l. | | 115 m | 46 m | 270 m | 81 m | 270 m | 360 m |
| climate zone (Köppen classification) | | marine west-coast (Cfb) | humid continental (Dfb) | sub-arctic (Dfc) | marine west-coast (Cfb) | sub-arctic (Dfc) | sub-arctic (Dfc) |
| biome | | temperate | hemi-boreal | boreal | hemi-boreal | boreal | tundra |
| Dominating species | | Picea abies | Picea abies, Pinus sylvestris | Pinus sylvestris, Picea abies | Avena sativa, Hordeum vulgare, Triticum | bog mosses: Sphagnum papillosum Lindb., Sphagnum lindbergii Schimp., Sphagnum balticum (Russow) C.E.O. Jensen | Sphagnum spp. Eriophorum spp. Carex spp, ericacious shrubs |
| Mean tree height/ age | | 19 m | 25 m | 20 m | - | - | - |
| Mean stand age | | 35 yrs | 120 yrs | 100 yrs | - | - | - |
| Understorey and ground vegetation | | mosses | Vaccinium myrtillus L., Vaccinium oxycoccos, mosses, flowers | Vaccinium vitis-idaea L., Vaccinium myrtillus L. | | Eriophorum, dwarf-shrubs: Vaccinium oxycoccos, Andromeda polifolia, Trichophorum cespitosum | Empetrum nigrum, Vaccinium vitis-idaea L., Rubus chamaemorus; Cyperaceae, Eriophorum |
| mean annual temperature | | 7.0 °C | 5.6 °C | 1.8 °C | 6.4 °C | 1.2 °C | -0.1 °C |
| mean annual precipitation | | 830 mm | 544 mm | 614 mm | 709 mm | 523 mm | 332 mm |
| Continuous measurements | | | | | | | |
| Turbulent fluxes | $CO_2$ | 27 m | 36 m | 34.5 m | 2.2 m | 2.1 m | $CO_2$ |
| | $H_2O$ | 27 m | 36 m | 34.5 m | 2.2 m | 2.1 m | 2.2 m |
| | $CH_4$ | - | - | - | 2.2 m | 2.1 m | 2.2 m |
| | Momentum | 27 m | 36 m | 34.5 m | 2.2 m | 2.1 m | 2.2 m |
| | Sensible heat | 27 m | 36 m | 34.5 m | 2.2 m | 2.1 m | 2.2 m |
| | Latent heat | 27 m | 36 m | 34.5 m | 2.2 m | 2.1 m | 2.2 m |
| Radiative fluxes | Incoming short-wave | 150 m, 50 m | 101.5 m, 55 m | 2 x 50 m | 4 m | 4 m | 2.2 m |
| | Outgoing short-wave | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Incoming long-wave | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Outgoing long-wave | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Net radiation (from 4 components) | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Incoming PAR | 150 m, 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Diffuse incoming PAR | 150 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Outgoing PAR | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | PAR below canopy | 4 x 4 transects | 4 x 4 transects | 4 x 4 transects | - | - | 5 m |
| | Spectral reflectance | 100 m | 55 m | 50 m | 4 m | 4 m | - |
| Soil fluxes | Soil heat flux | 4 x -0.05 m | 4 x -0.05 m | 4 x -0.05 m | 4 x -0.05 m | 4 x -0.05 m | 5 m |
| State variables | Air temperature profile | 14 levels | 14 levels | 14 levels | 5 levels | 5 levels | 4 x -0.05 m |
| | CO2 profile | 14 levels1 | 14 levels1 | 14 levels1 | 5 levels | 5 levels | 5 levels |
| | H2O profile | 14 levels | 14 levels | 14 levels | 5 levels | 5 levels | 5 levels |
| | CH4 profile | - | - | - | 5 levels | - | 5 levels |
| | Relative humidity | 24 m, 27 m | 37 m, 29 m | 32.5 m | 2.2 m | 2.0 m, 2.2 m | 2.5 m |
| | Wind speed/direction (sonic) | 30 m | 36 m | 34.5 m | 2.2 m | 2.1 m | 2.2 m |
| | Air pressure | 3.5 m | 1.5 m | 2 m | 1 m | 1.2 m | 1.7 m |
| | Soil temperature profile | 4 x 5 | 4 x 5 | 4 x 5 | 4 x 5 | 4 x 5 | 4 x 5 |
| | Soil moisture profile | 4 x 5 | 2 x 5 | 4 x 5 | 4 | 4 | 4 |
| | Ground water level | 4 | 2 | 4 | 4 | 4 | 4 |
| | Snow depth | 1 | 1 | 1 | 1 | 1 | 1 |
| | Precipitation | 2 | 2 | 2 | 2 | 2 | 2 |
| | Tree trunk surface temperature | 4 x 4 x 3 | 4 x 4 x 3 | 4 x 4 x 3 | - | - | - |
| | Canopy IR temperature | 50 m | 55 m | 50 m | 4 m | 4 m | 5 m |
| | Ground height | - | - | - | 2 m | 2 m | 1.5 m |
| Periodic measurements | | | | | | | |
| soil | soil carbon stocks | 1 / 10 years | 1 / 10 years | 1 / 10 years | 1 / 10 years | 1 / 10 years | 1 / 10 years |
| trees | GAI (hemispheric | 6/year | 6/year | 6/year | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | al pictures) | | | | | | |
| | above ground biomass (AGB) | 1/ 3 years | 1/ 3 years | 1/ 3 years | | | |
| | Nutrient analysis and Leaf Mass Area (foliar sampling) | 1/year | 1/year | 1/year | | | |
| | Woody debris | 1/year | 1/year | 1/year | | | |
| mosses | GA (percentage cover) | 2/year | | | 2/year | 2/year | 2/year |
| | NPP (yearly net change in biomass) | 1/year | | | 1/year | 1/year | 1/year |

## Table 2.2 ICOS Sweden Atmosphere station parameters

| **Atmospheric stations** | **Hyltemossa** | **Norunda** | **Svartberget** |
|---|---|---|---|
| coordinates | 56°06'N, 13°25'E | 60°05'N, 17°29'E | 64°10'N, 19°47'E |
| Scientific PI | Michal Heliasz, LU | Meelis Mölder, LU | Per Marklund, SLU |
| ***Continuous Measurements*** | | | |
| gas concentrations: CO, $CO_2$, $CH_4$, $H_2O$ | 30 m, 70 m, 150 m | 32 m, 58 m, 100 m | 35 m, 85 m, 150 m |
| PBL/cloud base height | 1 | 1 | 1 |
| Wind speed/direction, air temperature/humidity | 30 m, 70 m, 150 m | 32 m, 58 m, 100 m | 35 m, 85 m, 150 m |
| Turbulent fluxes | Ecosystem station | Ecosystem station | Ecosystem station |
| ***Periodic sampling*** | | | |
| Flask sampling; CO, $CO_2$, $CH_4$, $H_2O$, $SF_6$, $H_2$, $^{12/13}CO_2$ , $^{12/13}CH_4$ | 150 m | 100 m | 150 m |
| Sampling of radiocarbon $^{14}C$ | 150 m | 100 m | 150 m |

## Table 2.3 ICOS Sweden Ocean station parameters

| **Marine stations** | | **Östergarnsholm** |
|---|---|---|
| Scientific PIs | | Anna Rutgersson, UU |
| *Continuous measurements* | | |
| Turbulent fluxes | $CO_2$ | 1 |
| | $H_2O$ | 1 |
| | Momentum | 3 |
| | Sensible heat | 3 |
| Radiative fluxes | Global radiation | 2 |
| Water measurements | Temperature profile | 4 |

| | | |
|---|---|---|
| | Salinity profile | 4 |
| | Surface $CO_2$ | 1 |
| | Surface Oxygen | 1 |
| | Surface Temperature | |
| | Chlorophyll fluorescence | |
| | Turbidity | |
| | Phycocyanin fluorescence | |
| | CDOM fluorescence | |
| | Surface salinity | |
| State variables | Air temperature profile | 5 |
| | $CO_2$ profile | 4 |
| | $H_2O$ profile | 4 |
| | Wind profile | 5 |
| | Relative humidity | 1 |
| | Precipitation | 1 |
| *Periodic sampling* | | |
| Water sampling | Nitrogen | x |
| | Phosphorous | x |
| | Silica | x |
| | Salinity | |
| | Alkalinity | |

# Appendix 3: List of abbreviations and acronyms

### *ICOS RI (European level)*

ATC – Atmosphere Thematic Center
AS – Atmosphere stations
CAL – Central Analytical Laboratory
CFs – Central facilities (ETC, ATC, OTC and CAL)
CP – Carbon Portal
ES –Ecosystem station
ETC – Ecosystem Thematic Center
ERIC – European Research Infrastructure Consortium
ESFRI - European Strategy Forum on Research Infrastructures
FOS – Fixed Ocean station
HO – Head office
ICOS RI – Integrated Carbon Observation System Research Infrastructure
OS – Ocean station
OTC – Ocean Thematic Center
SOOP – ship of opportunity

### ICOS Sweden

CO – ICOS Sweden's Coordination Office
SAC – ICOS Sweden's Scientific Advisory Committee
SCG – ICOS Sweden's Station Coordination Group
SPI – ICOS Sweden Station Principal Investigator

### ICOS Sweden partners

LU – Lund University
GU – Gothenburg University
PFS - Swedish Polar Research Secretariat
SMHI –Swedish Meteorological and Hydrological Institute
SLU – Swedish University of Agricultural Sciences
UU – Uppsala University

### Other

GHG – greenhouse gas
SRC –Swedish Research Council (in Swedish VR – Vetenskapsrådet)