ICOS National Network Sweden

ICOS Sweden

Annual Report 2018

Lunds universitet · Göteborgs universitet · Stockholms universitet · Uppsala universitet · SLU · Polarforskningssekretariatet (Swedish Polar Research Secretariat) · Vetenskapsrådet

The Board of ICOS Sweden endorsed this Annual Report 2018 on 27 March 2019. The report is complemented by other documents from ICOS Sweden, including the Operational Plan for 2019, and the Strategic plan 2019-2024.

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MADE IN SWEDEN

Foreword from the ICOS Sweden management team

How is ICOS Sweden important for you?

The overall aim of ICOS is to facilitate the research field of bio-geoscience to understand the Earth system and to derive applied knowledge that supports climate action. Such research has high societal impact. Scientific knowledge on carbon emissions, sinks, and trends advances the fulfilment of the United Nation's Sustainable Development Goals and the European Union's Societal Challenges, especially the ones concerning climate change. ICOS also supports efforts to comply with the COP23 Paris Agreement resolutions with its ambitious targets to reduce the anthropogenic impact on the global climate and, for the Swedish case, to comply with the Swedish Climate Policy Framework.

ICOS Sweden provides otherwise scarce data from northern latitudes, which are undergoing the fastest climate change in the world. Being a European partner, ICOS Sweden also contributes to a network of standardized measurements with broad geographical coverage that enables studies over larger regions. By providing long term, high quality measurement data, interoperable with other systems and adapted to global standards, ICOS assures delivery of trustful data. All data is openly available and our ICOS Sweden sites are open for own field trials.

ICOS Sweden annual report 2018

This report inform about our activities during 2018 that was mainly focused on the labeling process of our stations in order to get them certified as ICOS stations, and to make all our data available, both ICOS data and complementary data from our sites. To date, all our atmosphere stations and two of our ecosystem stations are certified, being among the first stations in ICOS RI receiving this label. Most of our pre-ICOS label data is available for download and goes back to 2014.

We also invite you to a view behind the curtains and give some examples of projects presently using our sites as a motivation for the various type of research that ICOS contributes to. Our stations, their geographical setting, and equipment are also described as well our organization.

Enjoy reading and feel free to contact us for more information!

Contents

Introduction to ICOS Sweden

The Integrated Carbon Observation System Sweden, ICOS Sweden is a part of the pan-European distributed research infrastructure ICOS RI. The ICOS RI makes critical measurements of climate forcing trace gases (greenhouse gases, GHGs), using an in situ observation network. Those data are integrated to provide a knowledge base for necessary climate action. ICOS RI measures every component needed to contribute to a deeper understanding of the carbon cycle and its perturbations. This is accomplished by the integration of standardized observation networks in multiple domains (atmosphere, terrestrial ecosystems, and oceans) and their connections between the carbon balance of pristine and perturbed ecosystems. ICOS Sweden contributes to this goal of a continental scale understanding with measurements within each of these domains across the unique latitudinal gradient that characterizes Swedish environments.

Northern biomes, e.g. boreal forests and wetlands, have been sequestering carbon from the atmosphere since deglaciation 10000 years ago and they are at particular risk of climate induced degradation and loss due to rapid warming in northern high latitudes (IPCC). This will have severe implications to the Swedish economy and the national commitment to reduce GHG emission via natural ecosystem sinks. For marine systems, the increased levels of carbon dioxide (CO_2) in the atmosphere increases acidification which both decreases the subsequent marine absorption of the CO_2 and is an additional stressor for sensitive marine ecosystems. Because of the country's latitudinal extent and topography, many of Sweden's sensitive ecosystems will be affected by a warming climate and are at risk of being irreversibly damaged. At the same time, Sweden's geography provides an opportunity to observe and study changing climate system interactions on these sensitive ecosystems. ICOS Sweden is thus a critical component of the European-wide ICOS RI for information on the changing climate effects on terrestrial ecosystems and marine environments at high latitudes across temperate to sub-arctic climates.

Vision and Aims

ICOS Sweden will continue to be a part of a modern research infrastructure that provides data and access to advanced research stations within representative northern ecosystems. This establishes context and information that enhances our understanding of the interactions between land surface processes, including human activities, and the climate system. ICOS Sweden aims to have a central role in the support and promotion of Swedish and international research collaborations, provide test sites for national inventory systems, and site histories and databases that will promote advanced research. ICOS Sweden is a key resource for national and international climate impact research, earth system modeling and the factual basis to support and evaluate climate actions. ICOS Sweden will stimulate scientific studies and modelling efforts aiming at quantitative understanding of GHG emissions, sinks and trends and at contributing to the evaluation of Sweden meeting its emission targets.

To reach these aims, ICOS Sweden operates a network of measurement stations equipped with the most modern instrumentation available. Most importantly, each station has well trained personnel to deliver first class services to collaborative scientists and communities using its facilities. ICOS Sweden is fully integrated with, and plays a central role in the pan-European ICOS (ICOS RI) to promote and support national and international collaboration. It is designed to be interoperable with other environmental in situ and remote sensing infrastructures. Most stations have been operational since 2014, delivering open access data.

Sweden's ICOS sites are located in three ecosystem types characteristic for Sweden: northern forests, northern mires, and the Baltic Sea.

Forests covers ~70% of Sweden's land surface and coniferous species contribute >80% of the standing volume and represent a large economic value. They are also a key element in Sweden's strategy to reduce GHG emissions. Globally northern boreal forests are one of the major contributors to northern hemisphere CO2 sink.

Boreal mires cover ~3% of the earth's land area but contain ca. 30% of the global pool of soil organic carbon and represent a significant source of atmospheric methane (CH_4). Mire ecosystems are characteristic of boreal landscapes including large areas of Sweden. Abisko-Stordalen site is unique to the international ICOS infrastructure as the only sub-arctic permafrost site.

The Baltic Sea is the world's largest brackish water body. It drains nearly 20% of Europe and is heavily influenced by surrounding natural and human terrestrial systems. It is affected by eutrophication, acidification and climate change.

ICOS Sweden infrastructure

ICOS Sweden makes measurements from stations spread along a North-South latitudinal gradient from Abisko-Stordalen in the north to Hyltemossa in the south: 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. The three atmospheric stations are co-located with ecosystem stations.

The stations represent the different climate zones found in Sweden. They are unique stations in the continental scale of ICOS RI.

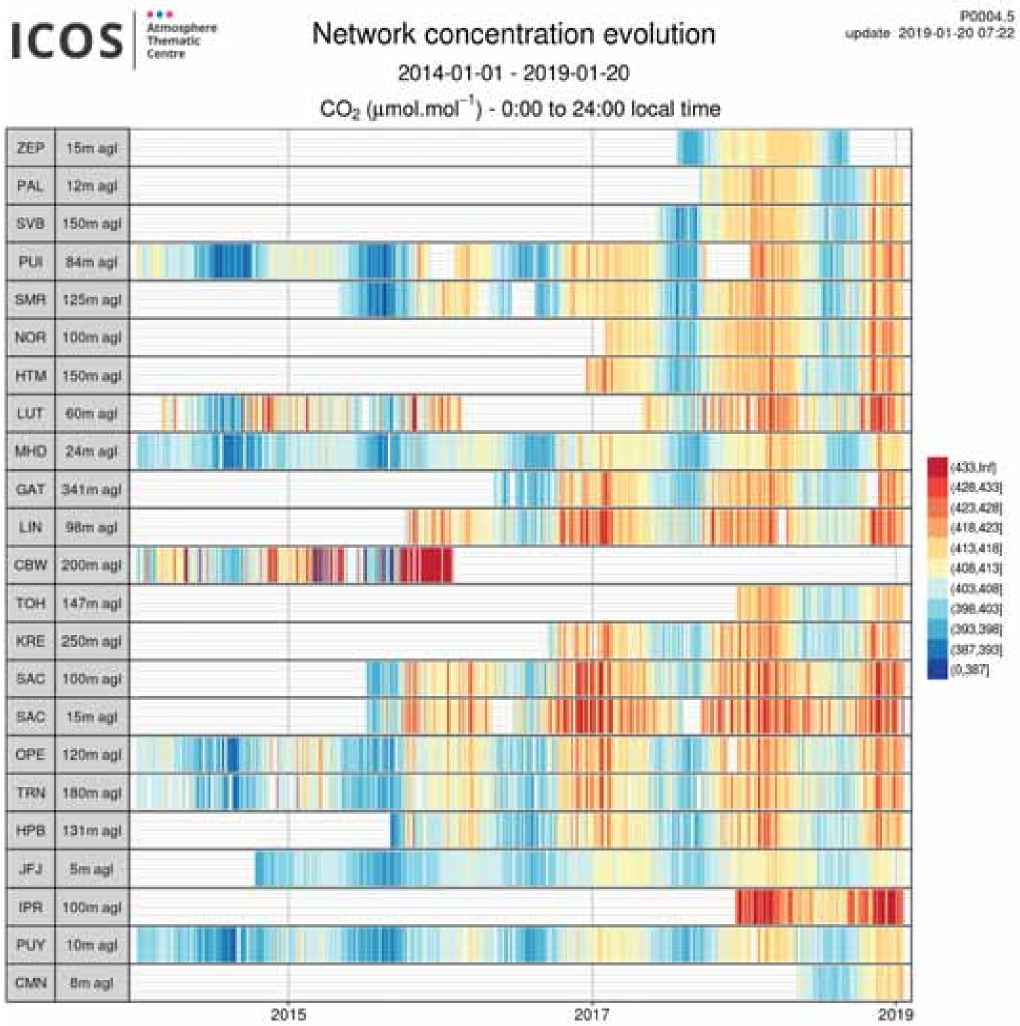
ICOS Sweden national station network

ICOS atmospheric stations

ICOS Sweden runs three out of a total of 33 Atmosphere stations within ICOS RI, monitoring regional changes in greenhouse gas concentrations. Each of the stations observes an area hundreds of kilometers wide around the station thanks to the mixing property of the atmospheric circulation. Thus the ICOS RI network covers most of the participating countries.

Atmosphere stations continuously measure varying concentrations of CO_2, CH_4, CO and radiocarbon-CO_2. These data, together with meteorological parameters, from all stations are processed in a dedicated facility, the Atmosphere Thematic Centre (ATC). The performance of the stations is further assessed by the ICOS Atmosphere Mobile Lab, capable of independent GHG observations campaign-wise carried out in parallel to the stations in-situ observations.

Data from the Atmosphere stations are also part of the NOAA GLOBALVIEW ObsPack products.



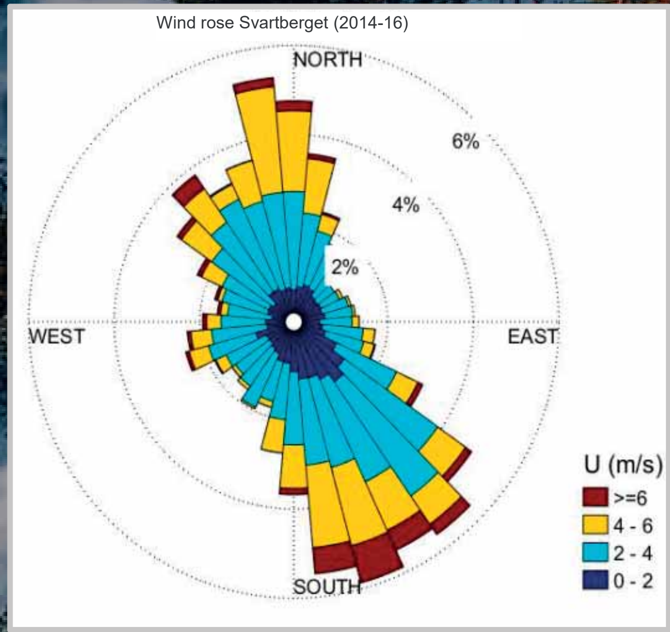
Svartberget – certified Class 1 ICOS Atmosphere station

Coordinates: LAT: 64.256N, LON: 19.775E
Elevation: 267 m
SPI: Dr Mikaell Ottosson Löfvenius, from March 2019: Per Marklund
Hosted by: SLU
Co-location with other RIs: SITES

Svartberget site is located in the northern Swedish boreal forest, about 70 km west of the Gulf of Bothnia. Ridges, valleys, rivers and lakes stretching from northwest to southeast characterize the landscape and the tower is situated on a gentle slope towards southeast. Spruce and pine forests dominate the landscape land use with some minor agricultural fields, mostly along the river valleys and closer to the sea.

The only larger municipalities in 100 km radius are Umeå (120t inhabitants, SE), Lycksele (8.5t inhabitants, NNW), and Skellefteå (72t inhabitants, NE).

Svartberget AS has received the ICOS RI certificate in spring 2018.



©Konsta Punkka

Norunda – certified Class 1 ICOS Atmosphere station

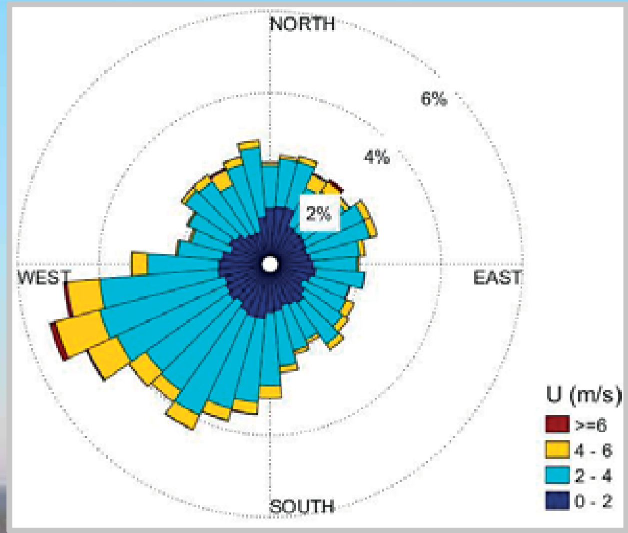
Coordinates: LAT: 60.086N, LON: 17.479E
Elevation: 46 m
SPI: Dr Meelis Mölder
Hosted by: Lund University
Co-location with other RIs: ACTRIS Sweden, NordSpec

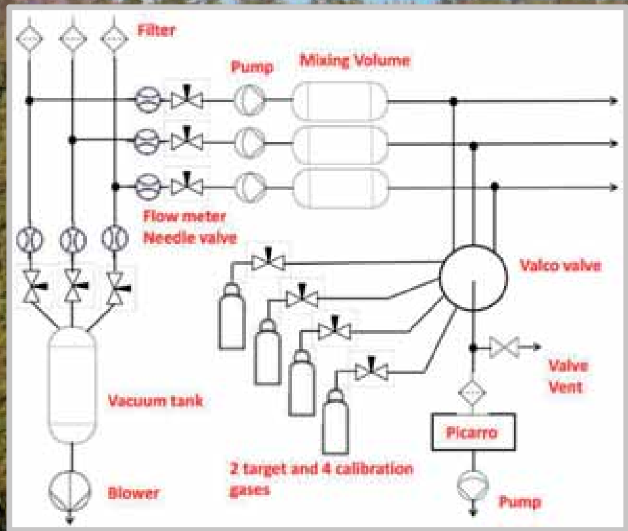
The Norunda station is located in the southern part of the boreal forest zone north of the capital Stockholm. The area is flat with small-scale variations in altitude (up to 10 m). The site is dominated by Norway spruce and Scots pine with a small fraction of birch trees. 70 km to the East runs the coastline to the Sea of Åland which devides the Gulf of Bothnia from the Baltic Sea.

Within a radius of 100 km, there are several cities with > 17t inhabitants to the South of Norunda, including the Swedish capital Stockholm with 1.4 mio inhabitants. To the North, only two cities are within the 100 km radius.

Norunda AS has received the ICOS RI certificate in spring 2018.

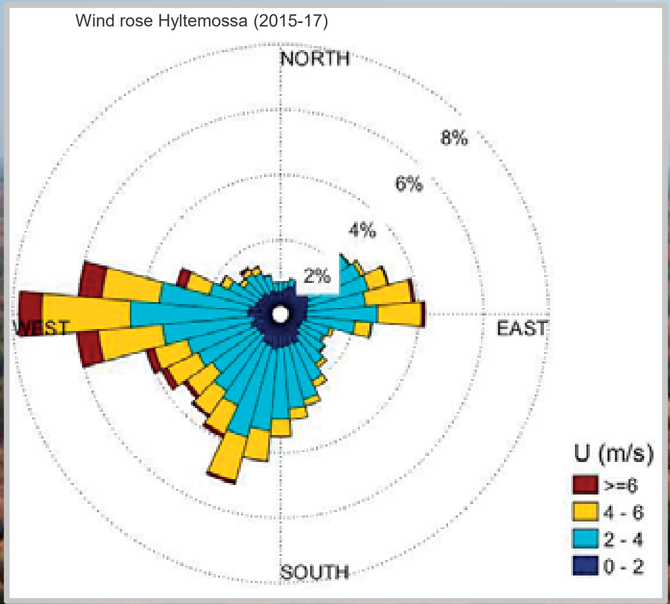
Wind rose Norunda (2015-17)





Hyltemossa – certified Class 1 ICOS Atmosphere station

Wind rose:



Coordinates: LON: 56.098N, LAT: 13.419E
Elevation: 160 m
SPI: Dr Michal Heliasz (CV)
Hosted by: Lund University
Co-location with other RIs: ACTRIS Sweden, NordSpec

Hyltemossa is located approximately 60 km north of the 3rd largest Swedish city Malmö, 40 km east of Helsingborg and approximately 70 km northeast of the Danish capital Copenhagen.

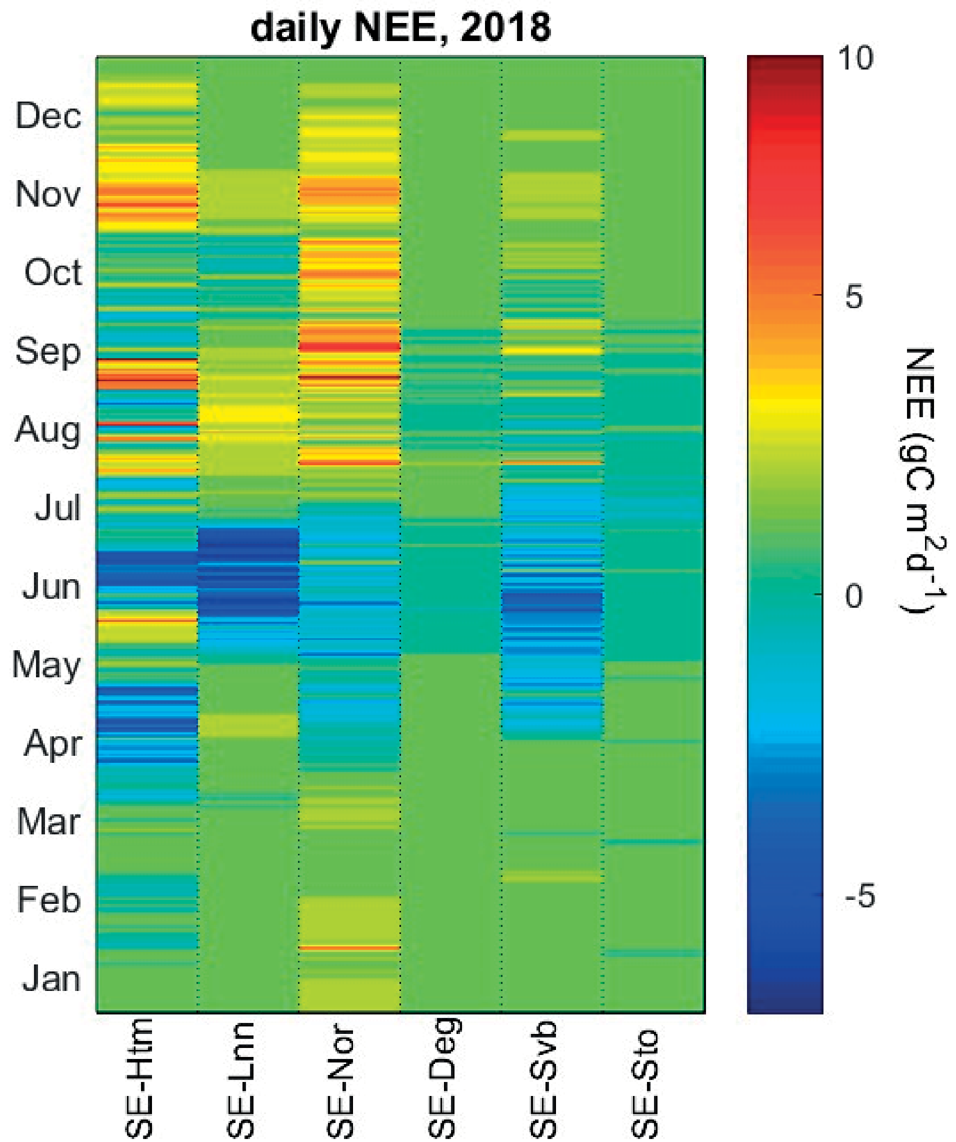
The site around the tower is dominated by Norway spruce. The forest floor is mainly covered by moss. Further than 600 m from the tower there is mosaic consisting of forests, clear cuts and farm fields. Within the radius of 100 km elevation changes between 0 - 200 m.a.s.l., in general quite flat. In near vicinity of the tower elevation gently changes by 35m.

Hyltemossa AS has received the ICOS RI certificate in spring 2018.

ICOS Ecosystem stations

The ICOS RI Ecosystem station network aims to sample climate and land-cover variability across Europe. In addition to GHG flux measurements, a large set of complementary data (including management practices, vegetation and soil characteristics) is collected to support the interpretation, spatial upscaling and modelling of observed ecosystem carbon and GHG dynamics. The applied sampling design was developed and formulated in protocols by the scientific community, representing a trade-off between an ideal dataset and practical feasibility. The protocols have been published in International Agrophysics in 2018. Complementary step-by-step instructions for the practical implementation of the protocols were developed by the Ecosystem Thematic Center Measurement and are available on the ETC homepage. Data which is mandatory within ICOS RI is coordinated by the ICOS RI Ecosystem Thematic Centre once the stations have received the ICOS RI certificate.

In total, there are six Class 2 Ecosystem stations run by ICOS Sweden: three forest sites, two mire sites and one agricultural site.



Abisko-Stordalen – candidate Class 2 ICOS Ecosystem station

Soil profile

Coordinates: LON: LAT: 68.356N, LON: 19.045E
Elevation: 267 m
SPI: prof Janne Rinne
Hosted by: Polar Research Secretariat
Co-location with other RIs: SITES, NordSpec
Köppen climate classification: sub-arctic (Cfc)
Biome: tundra
Dominating species: *Sphagnum*

The Abisko-Stordalen measurement site is located within the discontinuous permafrost zone, adjacent to the Lake Torneträsk. A large portion of the mire consists of a slightly elevated drained permafrost features (palsa), alternating by wetter depressions, which are not underlain by permafrost. Abisko-Stordalen is the only station within ICOS RI representing the sub-arctic region, being highly sensitive to climate change.

As a result of recent years warming in the area permafrost has been observed to degrade in many parts of the mires.

The site hosts an ICOS Ecosystem station which is in operation since 2013.

Degerö – candidate Class 2 ICOS Ecosystem station

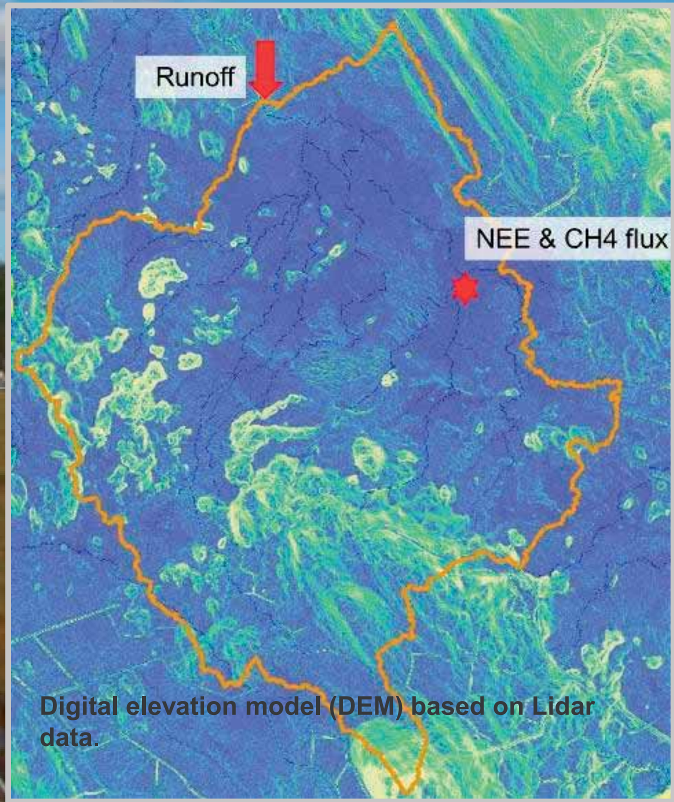
Coordinates: LON: 64.182N, Lon: 19.557E **Elevation:** 270 m
SPI: prof Mats Nilsson **Hosted by:** SLU, Umeå
Co-location with other RIs: SITES, NordSpec Köppen climate classification: sub-arctic (Dfc)
Biome: boreal **Dominating species:** bog mosses: *Sphagnum Balticum* L., *Sphagnum majus* L., *Sphagnum Lindbergii* L.

Degerö Stormyr is located in the Kulbäcksliden Experimental Forest near Vindeln in the county of Västerbotten, Sweden. It is a nutrient poor minerogenic mire, i.e. a fen, and thus typical for much of the mire area in the boreal region. The mire covers an area of 6.5 km2 and is situated on a highland between two major rivers, Umeålven and Vindelälven, ca 70 km from the Gulf of Bothnia.

Research started at the mire around 1910 on the risk of paludification of the forests in the boreal zone. Since 1995 intense research on mire biogeochemistry in general and green house gas biogeochemistry and exchange in particular have been conducted at the site. Measurements of the NEE using eddy-covariance technique started 2001 and measurements of CH_4 has been ongoing 2003 with chambers and since 2013 with EC. Discharge carbon export is ongoing since 2004 allowing for evaluation of the full carbon balance of an mire ecosystem.

The ICOS Degerö Station is also part of the recently established SLU whole mire catchment nitrogen fertilisation experiment, including three more adjacent mire catchment instrumented for both $CO_2$and CH_4 EC measurements.

The ICOS Degerö Stormyr Ecosystem station is in operation since 2013.



Digital elevation model (DEM) based on Lidar data.

Svartberget – candidate Class 2 ICOS Ecosystem station

Coordinates: LON: 64.256N, LON: 19.775E
Elevation: 267 m
SPI: Dr. Matthias Peichl
Hosted by: SLU, Umeå
Co-location with other RIs: SITES
Köppen climate classification: sub-arctic (Dfc)
Biome: boreal
Dominating species: *Pinus sylvestris* L., *Picea abies* L.

The Svartberget site is located in the Svartberget Experimental Forests. The experimental forest covers 1076 ha of boreal forest land and governs a manifold of research activities since 1923. A reference monitoring program of climate and water is active since 1980.

Svartberget Experimental Forests is a center for forest research in Sweden and provides key infrastructures for field based research on productive pine and spruce forest stands, mire and lake ecosystems and catchments. The Krycklan Catchment Study represents one of the most heaviest instrumented catchments worldwide. The large study area gives researchers unique opportunities to perform studies on both local and landscape levels and to establish large scale field manipulations.

The site hosts an ICOS Ecosystem station which is in operation since 2013.

Norunda – certified Class 2 ICOS Ecosystem station

Coordinates: LON: 60.086N, LON: 17.479E
Elevation: 46 m
SPI: Dr Meelis Mölder
Hosted by: Lund University
Co-location with other RIs: ACTRIS Sweden, NordSpec
Köppen climate classification: humid continental (Dfb)
Biome: hemi-boreal
Dominating species: *Picea abies* L., *Pinus sylvestris* L.

Norunda research station was established in 1994 about 30 km north of Uppsala, i.e., in the southern part of the boreal forest zone. The area is flat with small-scale variations in altitude (up to 10 m). The stand closest to the tower is about 120 years old with a mean tree height of 26 m. The shrub layer is dominated by blueberry, cranberry, moss, and flowers. At a distance of 500 m there are a few clear cuts. There is a small lake 1 km to the North.
During the last decades, the site has been used for studies of exchanges of greenhouse gases (CO_2 and CH_4 energy and water using micrometeorological methods (eddy covariance and gradient).

The site hosts an ICOS Ecosystem station which is in operation since 2013. SE-Nor received the ICOS RI certificate as Class 2 Ecosystem station in autumn 2018.

Lanna – candidate Class 2 ICOS Ecosystem station

Coordinates: LON: 58.34063N, LAT: 13.101768E
Elevation: 75 m
SPI: Dr Per Weslin
Hosted by: University of Gothenburg
Köppen climate classification: marine west-coast (Cfb)
Biome: hemi-boreal
Dominating species: cereals, rape, peas
2018: oats
2019: peas

Lanna is the most northern agricultural site within ICOS-Europe. The measurement station is located within the SLU research station Lanna which has been in operation since 1929. ICOS Lanna is thus operated in close cooperation with SLU.

The station is set on clay soil and representative for the most dominate cereal production in Sweden. It has a strong focus on elucidating the control mechanisms for production and emissions of laughing gas N2O during winter periods.

The site is flat and homogeneous, making it close to ideal for micrometeorological studies.

photo: P. Weslien

photo: P. Weslien

Hyltemossa – certified Class 2 ICOS Ecosystem station

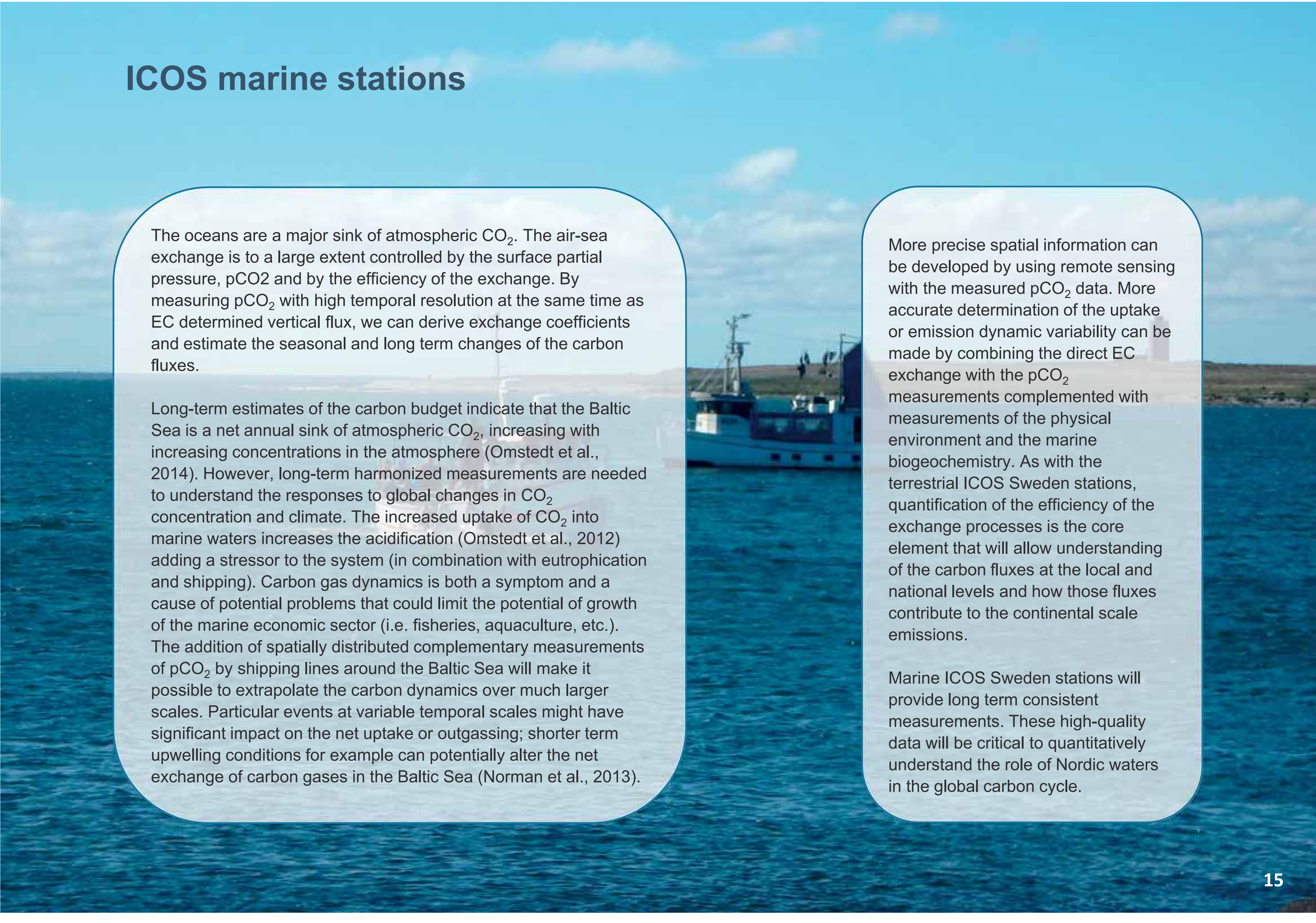
Coordinates: LON: 56.098N, LAT: 13.419E
Elevation: 160 m
SPI: Dr Michal Heliasz
Hosted by: Lund University
Co-location with other RIs: ACTRIS Sweden, NordSpec
Dominating species: *Picea abies* L.

Hyltemossa is located a few kilometers south of Perstorp, in northwestern Skåne in a 30 year old managed spruce forest. The site around the tower is dominated by Norway spruce (*Picea abies* L.) with a small fraction of birch trees (*Betula sp.* L.) and single occurrence of Scots pine (*Pinus sylvestris* L.). Understorey vegetation is sparse. The forest floor is mainly covered by a thick moss layer.

The site was established in 2014 and hosts an ICOS Ecosystem station which is in operation since 2015. Hyltemossa received the ICOS RI certificate in spring 2018 as the 1st forest Ecosystem station within ICOS RI.


photo: SE-Htm


photo: SE-Htm



ICOS marine stations

The oceans are a major sink of atmospheric CO_2. The air-sea exchange is to a large extent controlled by the surface partial pressure, pCO2 and by the efficiency of the exchange. By measuring pCO_2 with high temporal resolution at the same time as EC determined vertical flux, we can derive exchange coefficients and estimate the seasonal and long term changes of the carbon fluxes.

Long-term estimates of the carbon budget indicate that the Baltic Sea is a net annual sink of atmospheric CO_2, increasing with increasing concentrations in the atmosphere (Omstedt et al., 2014). However, long-term harmonized measurements are needed to understand the responses to global changes in CO_2 concentration and climate. The increased uptake of CO_2 into marine waters increases the acidification (Omstedt et al., 2012) adding a stressor to the system (in combination with eutrophication and shipping). Carbon gas dynamics is both a symptom and a cause of potential problems that could limit the potential of growth of the marine economic sector (i.e. fisheries, aquaculture, etc.). The addition of spatially distributed complementary measurements of pCO_2 by shipping lines around the Baltic Sea will make it possible to extrapolate the carbon dynamics over much larger scales. Particular events at variable temporal scales might have significant impact on the net uptake or outgassing; shorter term upwelling conditions for example can potentially alter the net exchange of carbon gases in the Baltic Sea (Norman et al., 2013).

More precise spatial information can be developed by using remote sensing with the measured pCO_2 data. More accurate determination of the uptake or emission dynamic variability can be made by combining the direct EC exchange with the pCO_2 measurements complemented with measurements of the physical environment and the marine biogeochemistry. As with the terrestrial ICOS Sweden stations, quantification of the efficiency of the exchange processes is the core element that will allow understanding of the carbon fluxes at the local and national levels and how those fluxes contribute to the continental scale emissions.

Marine ICOS Sweden stations will provide long term consistent measurements. These high-quality data will be critical to quantitatively understand the role of Nordic waters in the global carbon cycle.

Östergarnsholm – candidate Class 1 ICOS Ocean station

Coordinates: LON: 64.182N, LON: 19.557E
SPI: prof Anna Rutgersson
Hosted by: Uppsala University

The Östergarnsholm site, located 4 km from the eastern coast of Gotland, is situated on a small, flat island which stretches about 2 km in the W-E and N-S direction respectively. The southern part is very flat and rises only a few meters above sea surface and consists of mainly of rocks. There is a few single trees in the northeastern corner of the island far away from the measurement location.

The station consists of a 30 m high tower and several buoys 1 km south-east of the tower. The flux footprint of the tower measurements have in several studies been shown to well represent undisturbed sea conditions for the right wind directions.

Östergarnsholm will deliver data according to the protocols of the Ocean Thematic center (OTC), but also flux measurements for air-sea exchange of CO_2.

Aerial view over Östergarnshom.

A view behind the curtains

Users of the infrastructure

ICOS Sweden and its data products is an infrastructure which is open to everyone. As research infrastructure, it is meant to be used by scientists to address different research questions. By organizing open door events or preparing easy to understand teaching material, it can even reach out to the general public to arouse interest and enlarge knowledge on ecosystem related climate issues. Elaborated products will be available for all the interested social stakeholders such as citizens, decision makers and media.

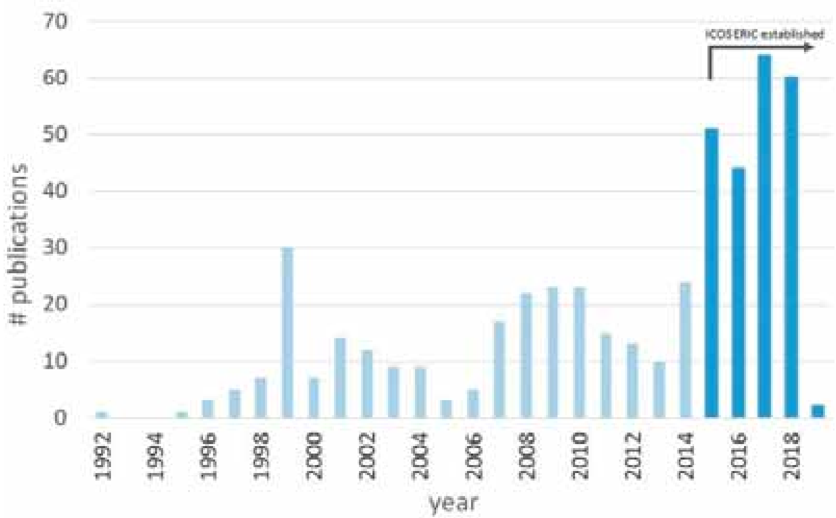
ICOS Sweden stations are used as destination of excursions and field courses at different levels and attracted by this 139 scientific visitors during 2018.

Scientific users of the infrastructure are researchers using the data produced by the measurement stations to address their research question. The data downloads of near real time and final quality controlled data sets has via the Carbon Portal has increased to 15781 during 2018, compared to 59 data requests by direct mail contact.

Scientific users of the ICOS Sweden infrastructure are also researchers coming to the stations adding installations or taking samples to answer their specific research question. During 2018, 54 project PIs were active at the ICOS Sweden stations.

On the following pages, some users of the ICOS Sweden infrastructure talk about their projects giving insight into the Science that is supported by ICOS Sweden by data or manpower or by simply giving access to infrastructure.

More detailed information on the usage of the infrastructure can be found in the annual user statistics report: http://www.icos-sweden.se/docs/publications/ICOS_Sweden_keynumbers_2018.pdf.



Number of per-reviewed publications related to stations which now belong to the ICOS Sweden research infrastructure. A reference list with start 2015 can be found on http://www.icos-sweden.se/referenceList.html

Understanding of the climatic and biotic drivers of BVOC emissions in Arctic ecosystems

contact: Roger Seco, Thomas Holst, Andreas Westergaard-Nielsen, Mikkel Sillesen Matzen, Tihomir Simin & Riikka Rinnan (Copenhagen University/DK)

photo: T. Holst

photo: T. Holst

The influence of biogenic volatile organic compounds (BVOCs) on atmospheric oxidation reactions and the resulting feedbacks on climate are increasingly acknowledged. Nevertheless, we lack understanding of the climatic and biotic drivers of BVOC emissions, especially for the terrestrial Arctic, which is experiencing rapid and drastic warming. This area is a more important BVOC source than previously thought and its BVOC emissions show an extreme temperature sensitivity. Arctic and alpine areas are experiencing strong climate warming at a pace twice as fast as the global average, resulting in permafrost thaw, which is expected to lead to a large carbon release in the form of GHG and BVOCs.

At Abisko-Stordalen, we deployed two Proton Transfer Reaction-Time of Flight-Mass Spectrometers (PTR-TOF-MS) during the whole growing season (June-October 2018) to measure the ecosystem fluxes of BVOCs with the Eddy Covariance technique. The observed fluxes, combined with multispectral camera images, will be used to assess the relationship between the canopy surface temperature, phenology and the volatile emissions of the tundra. The project, Tundra biogenic volatile emissions in the 21st century (TUVOLU), is funded by the European Research Council.

photo: R. Rinnan

Examples for scientific usage of ICOS Sweden stations

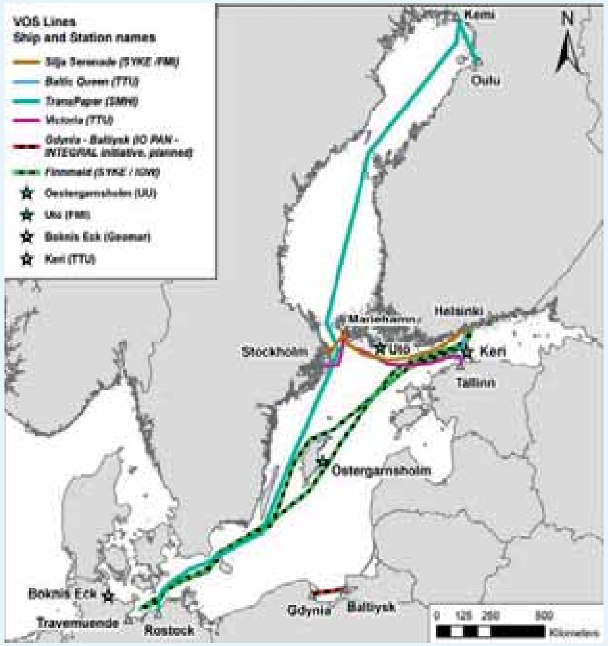
Building a hut around a PTR-TOF-MS instrument coupled to an eddy covariance mast to the left in the photo. Photo: R. Rinnan.

Installing a remote sensing setup to follow temporal changes in surface temperatures (infrared cameras), vegetation greenness (Normalized Difference Vegetation Index sensors and RGB timelapse cameras) as well as in photosynthetic efficiency (Photochemical Reflectance Index sensors). Photo: R. Rinnan.

BONUS INTEGRAL - Integrated carboN and TracE Gas monitoRing for the bALtic sea

contact: Gregor Rehder, Leibniz Institute for Baltic Sea Research Warnemünde

"Using ICOS and similar infrastructure for an improved environmental monitoring of the Baltic Sea"



Map of locations of infrastructure used within BONUS INTEGRAL.

BONUS INTEGRAL is an integrated project funded within the BONUS Blue Baltic Call. It comprises eight partners from five nations and runs from July 2017 to June 2020. BONUS INTEGRAL seeks to demonstrate and exploit the potential added value of the marine stations of ICOS and similar instrumentation for the ecosystem state assessment of the Baltic Sea. While the overall aim of ICOS is to provide European-wide carbon dioxide and other greenhouse gas (GG) concentration and flux data, an integration for the Baltic Sea region has not been pursued, and the added value of ICOS and related infrastructure for the Baltic Sea ecosystem assessment has not been exploited at all.

Integrating the different components and data streams of ICOS, related infrastructure, and pre-existing related data in the pan-Baltic Sea area will be in the core of BONUS INTEGRAL. Field studies will be conducted to assure operation and install amendments to existing infrastructure in maximizing innovation and gained knowledge. One major aim of the project is to provide best possible experimentally based seasonal surface concentration charts of carbon dioxide, methane and nitrous oxide over the Baltic Sea.

In the end, BONUS INTEGRAL aims to demonstrate the added value of using greenhouse gas data in combination with carbon system data, and promote project's findings towards a better, cost effective ecosystem based monitoring of the Baltic Sea.

more information: https://www.io-warnemuende.de/integral-home.html

Ecosystem-scale surface-atmosphere exchange of mercury at ICOS sites

Contact: Stefan Osterwalder (Université Grenoble Alpes), Anna Rutgersson (Uppsala University), Wei Zhu, Mats Nilsson, Kevin Bishop (SLU)

The toxic burden of anthropogenic mercury (Hg) pollution for human and ecosystem health is globally accepted by policy makers and has resulted in the signature of the UNEP Minamata Convention on mercury by over 100 countries. The 2013 convention aims to reduce Hg use and curb global anthropogenic Hg emissions to the atmosphere. However, since the middle ages over 1.5 Mio tons of anthropogenic Hg have been emitted to the environment forming large pools of legacy Hg in soils and the oceans. Re-emission of legacy Hg is now believed to account for about 60% of the Hg entering the atmosphere each year complicating the understanding of its biogeochemical cycle. We use the infrastructure of Swedish ICOS stations to investigate sink-source characteristics of atmospheric Hg in peatland, forest and marine ecosystems.

At the ecosystem station Degerö Stormyr we applied a novel micrometeorological system to derive the first annual Hg budget for a boreal peatland, based on continuous measurement of the peatland-atmosphere exchange of gaseous elemental mercury (Hg0). We show that evasion of Hg was about seven times greater than stream Hg export, and over two times greater than wet bulk deposition. The net ecosystem exchange of Hg0 might result from recent declines in atmospheric Hg concentrations that have turned the peatland from a net sink into a source of atmospheric Hg. At the atmospheric station Svartberget we investigate the role of Hg atmosphere-canopy and near ground atmosphere-soil exchange in the Hg biogeochemical cycle.

The fate of Hg in boreal forest ecosystems is compared with a study performed at the ICOS-CH ecosystem monitoring station in Davos-Seehornwald, Switzerland. At the oceanic station Östergarnsholm we combined measurements of Hg isotope signatures with micrometeorological and bulk methods to assess processes of the ocean-atmosphere exchange of Hg0 and to determine its net ecosystem exchange. We aim to improve parameterization in regional ocean-air exchange models for Hg by applying micrometeorological methods, e.g. during periods of high wind speeds.

The Swedish ICOS stations offer excellent conditions for long-term measurements of the net ecosystem exchange of Hg0 using micrometeorological techniques. Taking advantage of ICOS research infrastructure is a big asset for our Hg flux projects due to both, the free access to high precision all-season meteorological data and the contact to the research engineers who maintain both, instruments and data acquiring as well as the many specialists in micrometeorology.

reference: Osterwalder, S., K. Bishop, C. Alewell, J. Fritsche, H. Laudon, S. Åkerblom & M.B. Nilsson, 2017: Mercury evasion from a boreal peatland shortens the timeline for recovery from legacy pollution. *Scientific Reports*, 7:16022, DOI:10.1038/s41598-017-16141-7.

Robust estimation of vegetation seasonality from Landsat and Sentinel-2 Time Series Data

contact: Zhanzhang Cai (Lund University)

Satellite remote sensing technology can provide us with images of land surface on a regular basis. When remotely sensed satellites can frequently revisit the earth, they can be used to observe vegetation seasonality globally. In order to obtain globally daily observations from satellites (e.g., Advanced Very High-Resolution Radiometer, AVHRR, and the Moderate Resolution Imaging Spectroradiometer, MODIS) for precisely monitoring vegetation seasonality, the spatial resolution of satellite images are usually coarse (over hundreds meters). At this coarse resolution, surface objects are difficult to visually reflect in the images. The effects of varieties of land cover types, vegetation types, and atmospheric conditions accumulated within one pixel lead difficulties in validating the products from these coarse satellite images.

Sentinel-2 satellites, affiliated to the Earth Observation mission in the European Union’s Copernicus programme, were launched by the European Space Agency (ESA) and fully operated since 2017. They provide 10 m spatial resolution and 5 days temporal resolution of globally terrestrial observation. We developed a methodology, shape prior and box constrained separable least squares fitting to logistic model functions (Jönsson et al. 2018), for extracting vegetation seasonality from Sentinel-2 multispectral instrument (MSI) data, and we estimated phenology (e.g., Figure 1) and photosynthetic carbon uptake (e.g., Figure 2) with the new method.

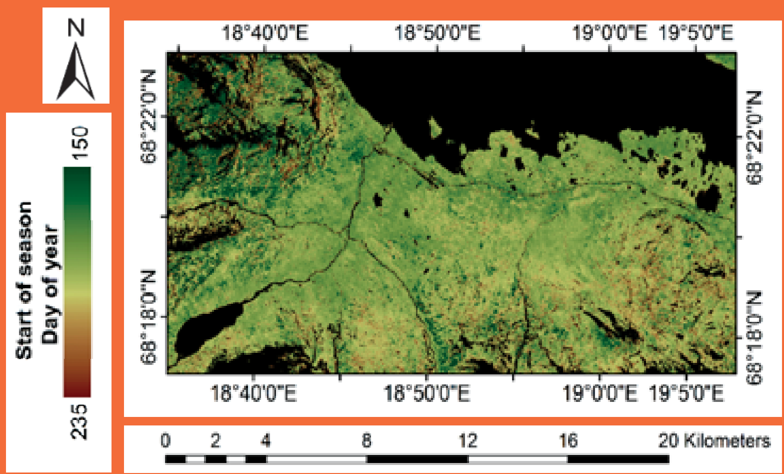


Figure 1. Start of season in 2017 in the surrounding area of Abisko.

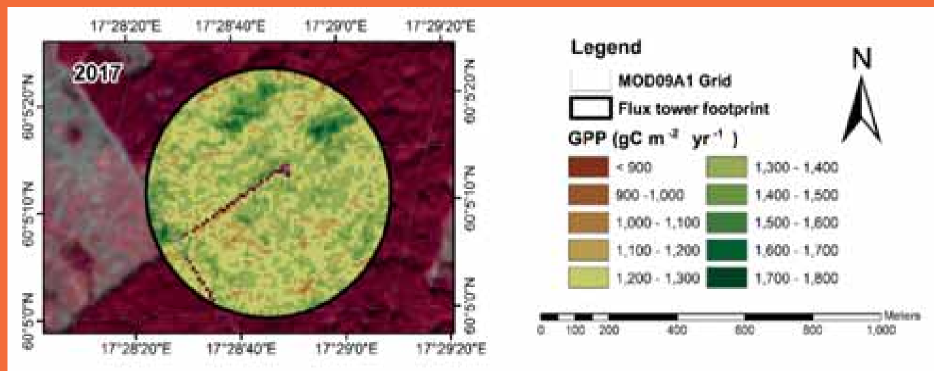


Figure 2. Annual Gross Primary Productivity in 2017 at the approximate footprint area of Norunda flux tower.

Examples for scientific usage of ICOS Sweden stations

For validating the estimation of phenology and photosynthetic carbon uptake from Sentinel-2, we used data from PhenoCam and eddy covariance measurements provided by ICOS Sweden. PhenoCam, also known as WebCam, provides near-ground and high-frequency RGB images. Objects, such as leaves, trucks, canopies, grass, can be visually identify from the images. We converted those RGB images to Green Chromatic Coordinates (GCC) for representing the state of vegetation in the fields and extracted vegetation phenological parameters, e.g., greenness rising and falling, from the smoothing curve (e.g., Figure 3 top). The phenological parameters from PhenoCam were as ground references to validate the phenological parameters estimated from Sentinel-2 two-band enhanced vegetation index (EVI2) time-series (e.g., Figure 3 Bottom). Our results indicate that Sentinel-2 data can provide more accurate estimation of greenness rising (8.1 days different from PhenoCam greenness rising) than estimation of greenness falling (17.3 days different from PhenoCam greenness falling).

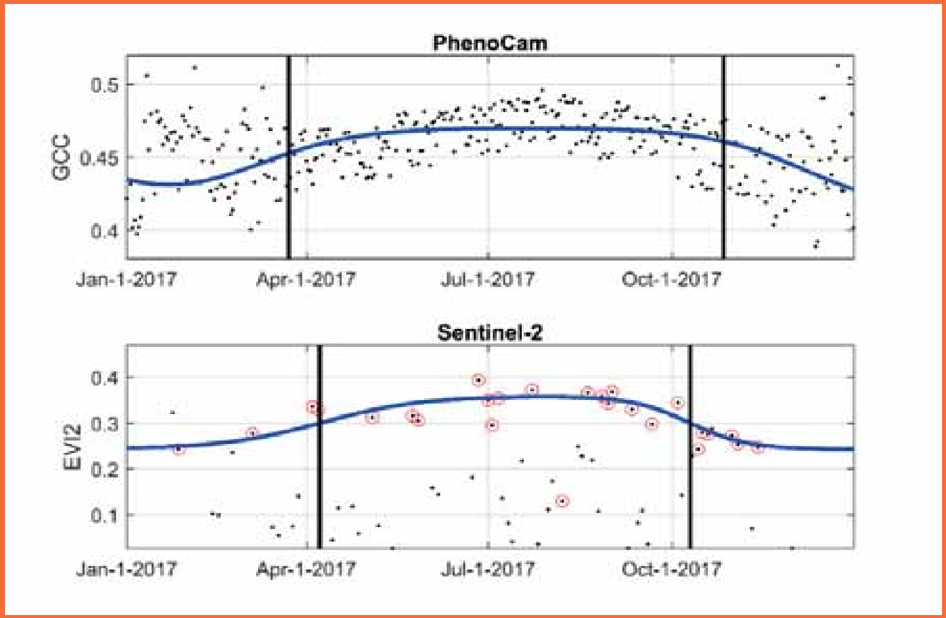


Figure 3. Greenness rising and falling in 2017 at Abisko-Stordalen site estimated from PhenoCam (top) and Sentinel-2 (bottom). Black dots are data from PhenoCam and Sentinel-2. Red circles are cloud free observation from Sentinel-2. Blue curve is smoothed time-series generated by our new method.

Gross primary productivities (GPP) reflect the ability of vegetation in photosynthetic carbon uptake from atmosphere. By using eddy covariance data from ICOS flux towers, in-situ daily GPP can be modelled (e.g., the blue curve in Figure 4) as references, and they can be used to validate the accuracy of Sentinel-2 modelled daily GPP (e.g., the red curve in Figure 4). Our results show that there is 1.60 g C m-2 day-1 difference in average between Sentinel-2 modelled GPP and flux towers modelled GPP. With Sentinel-2 high spatial resolution data, we can mapping the hotspots in footprint area of flux tower measurements and then quantify the homogeneity of the area covered by flux tower measurements (Figure 2).

reference: Jönsson et al, 2018. A Method for Robust Estimation of Vegetation Seasonality from Landsat and Sentinel-2 Time Series Data. Remote Sens. 2018, 10(4), 635; https://doi.org/10.3390/rs10040635

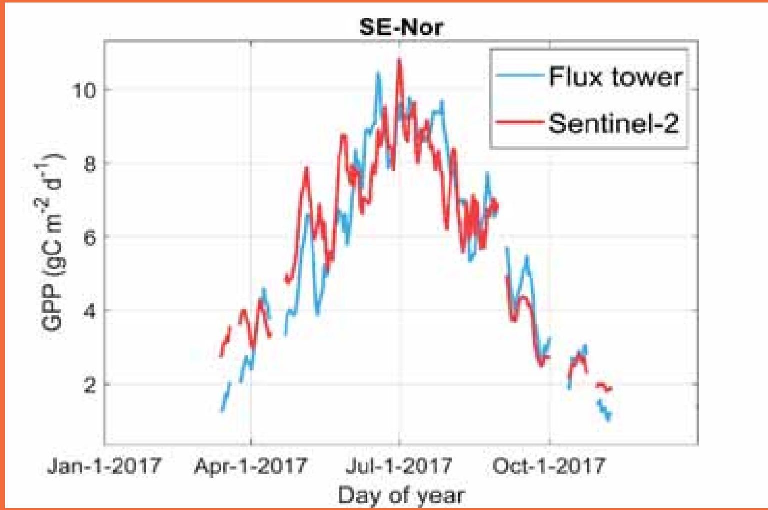


Figure 4. Daily Gross Primary Productivities in 2017 at Norunda site. The red curve shows modelled daily GPP from Sentinel-2 data, and the blue curve shows modelled daily GPP from flux tower.

Are the atmospheric particles created by the forest cooling or warming the climate?

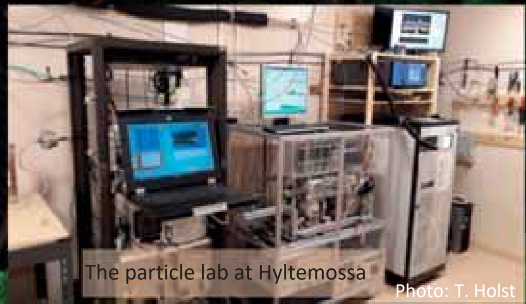
Contact: Adam Kristensson, Thomas Holst, Lund University

Many know that forests affect climate when the trees absorb carbon dioxide during photosynthesis, and due to afforestation and deforestation. What is less know is that the emissions of gaseous volatile organic compounds terpene (VOC) produce atmospheric particles, which also affect climate.

In two VR and FORMAS projects at Hyltemossa, we quantify the VOC emissions when the spruces are protecting themselves from insects, or want to attract pollinators, or when they are stressed.

We use high-time resolution instruments to measure these VOC and the particles that are formed from VOC, and how these particles cool the climate via solar light scattering or cloud formation. We can observe single soot particles emitted from fossil fuel or biomass combustion in Sweden and Europe. The VOC stick to the soot particles and affect their solar light absorption properties and thereby the heating of the climate.

In the end, are the VOC warming or cooling the climate via the particle formation route? Well, that's the million dollar question.



The particle lab at Hyltemossa

Photo: T. Holst

Photo: T. Biermann

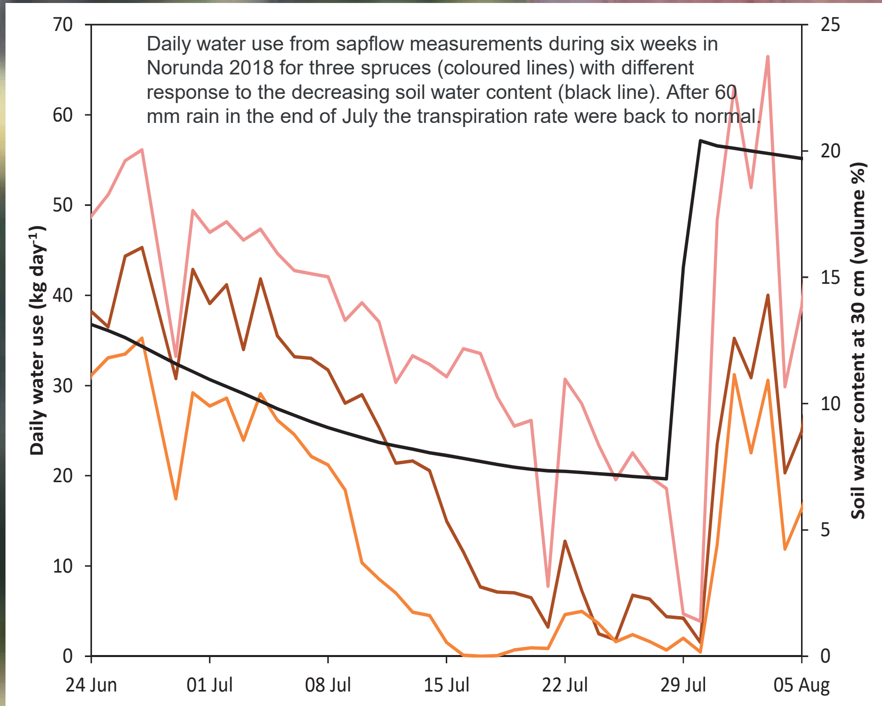
Drought stress responses of spruce and pine in Sweden

contact: Maj-Lena Linderson , Fredrik Lagergren, Anna Maria Jönsson (Lund University)

Consequences of changes in temperature and precipitation regimes for forest ecosystems and tree growth is a key concern, as forests are both influenced by ongoing climate change and contribute to mitigation via carbon sequestration and substitution effects. For Southern Sweden, future drier climate threatens both forest growth and health. Drought may lead to not only reduced growth but also lower tree defence against insect pests and fungi pathogens.

By sapflow techniques the water use from single trees can be measured at high temporal resolution at the passage through the stem. If a representative sample of trees is measured the data can be scaled up to stand level transpiration. An advantage compared to the ecosystem evapotranspiration from eddy covariance is that the same set of trees is always measured (no varying footprint). Sapflow also gives information of the variation of water use among individual trees and, as for Norunda, performance of different species in mixed stands.

In the beginning of 2017 the ground water levels in Sweden were exceptionally low, and we saw an opportunity to study possible effect of coming drought by installing sapflow measurement system at the ICOS sites Norunda and Hyltemossa. In Norunda both summers of 2017 and 2018 had long periods of drought and in Hyltemossa the summer of 2018 was exceptionally warm and dry. We are in the process of analysing the data, which show a strong effect of the drought but also a large variation among trees.



Daily water use from sapflow measurements during six weeks in Norunda 2018 for three spruces (coloured lines) with different response to the decreasing soil water content (black line). After 60 mm rain in the end of July the transpiration rate were back to normal.

Photo: A. Båth

An improved methodology for calculating ozone-sensitive periods for vegetation during the year

contact: Per Erik Karlsson, Gunilla Pihl Karlsson (IVL Swedish Environmental Research Institute Ltd.), Håkan Pleijel (University of Gothenburg)

On behalf of the Swedish Environmental Protection Agency, IVL Swedish Environmental Research Institute and the University of Gothenburg have developed proposals for improved methods for calculating ozone-sensitive periods during the year for important plant species in Sweden.

The Swedish Environmental Protection Agency intends to introduce new clarifications for the impact of ozone near the ground on vegetation in Sweden within the environmental quality objective Fresh Air. The new specifications will be based on the absorption of ozone through the stomatal openings to the interior of leaves and needles, so-called ozone flux.

There are periods of the year when different types of plants are less sensitive to ozone influences. For deciduous trees this applies to periods of the year when there are no leaves on the trees. For coniferous trees, the periods of the year apply when the trees are in winter dormancy.

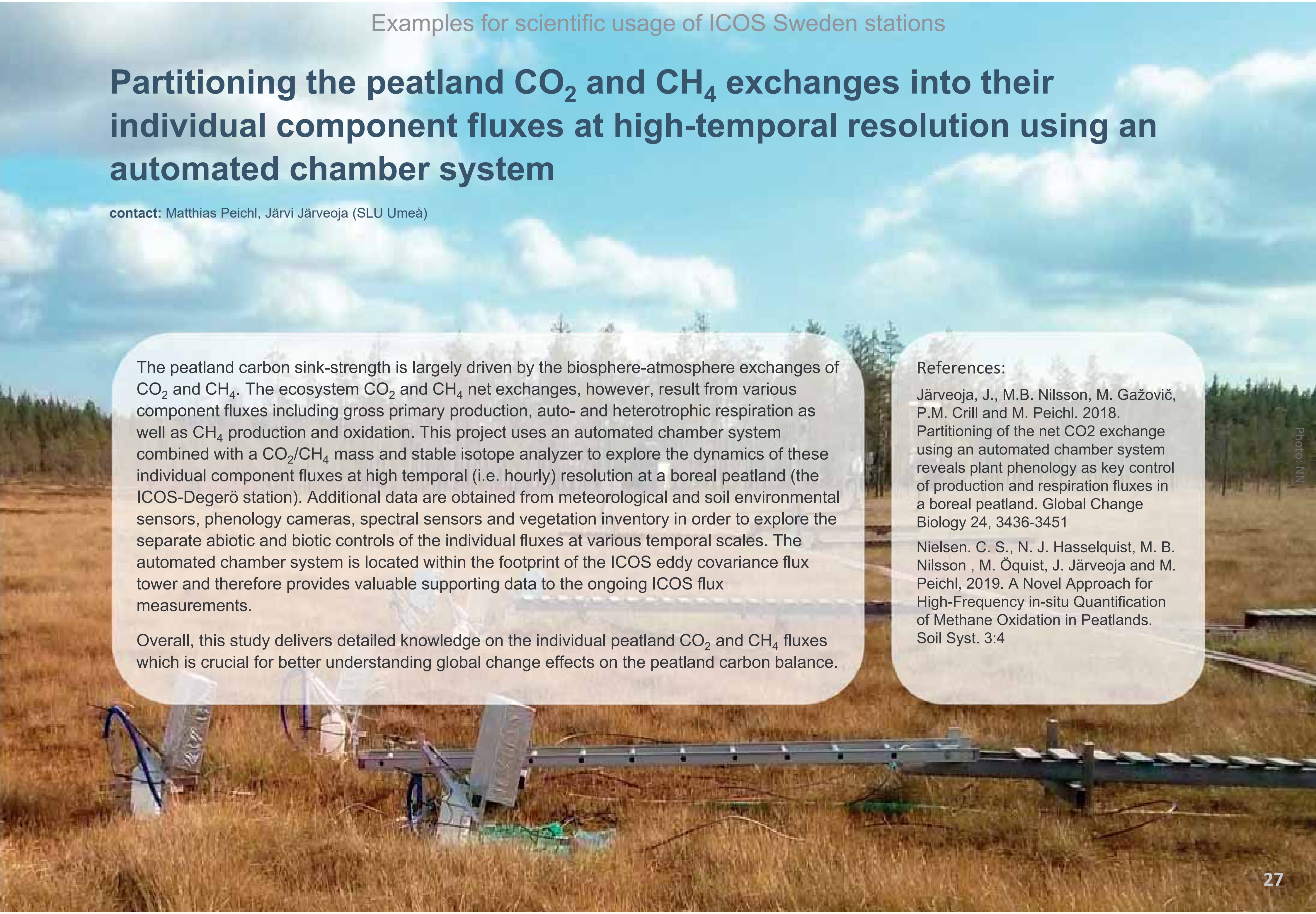
For spruce, e.g. the ozone sensitivity period is defined as between the time of when the trees leave their winter dormancy and begin an active gas exchange with the surrounding atmosphere and the time of autumn when the trees reduce their gas exchange and enter winter dormancy. For Norway spruce, the new methods has been based on micrometeorological measurements of the forest ecosystem's carbon dioxide exchange with the atmosphere, measured and calculated by ICOS Sweden at Hyltemossa, Norunda and Svartberget.

Finally the assessment was made that a connection between the start of the ozone sensitivity period for spruce and a simple meteorological index based on daily mean temperature could be constructed based on available data for NEE within ICOS Sweden.

photo: I. Lehner

Partitioning the peatland CO_2 and CH_4 exchanges into their individual component fluxes at high-temporal resolution using an automated chamber system

contact: Matthias Peichl, Järvi Järveoja (SLU Umeå)



The peatland carbon sink-strength is largely driven by the biosphere-atmosphere exchanges of CO_2 and CH_4. The ecosystem CO_2 and CH_4 net exchanges, however, result from various component fluxes including gross primary production, auto- and heterotrophic respiration as well as CH_4 production and oxidation. This project uses an automated chamber system combined with a CO_2/CH_4 mass and stable isotope analyzer to explore the dynamics of these individual component fluxes at high temporal (i.e. hourly) resolution at a boreal peatland (the ICOS-Degerö station). Additional data are obtained from meteorological and soil environmental sensors, phenology cameras, spectral sensors and vegetation inventory in order to explore the separate abiotic and biotic controls of the individual fluxes at various temporal scales. The automated chamber system is located within the footprint of the ICOS eddy covariance flux tower and therefore provides valuable supporting data to the ongoing ICOS flux measurements.

Overall, this study delivers detailed knowledge on the individual peatland CO_2 and CH_4 fluxes which is crucial for better understanding global change effects on the peatland carbon balance.

References:

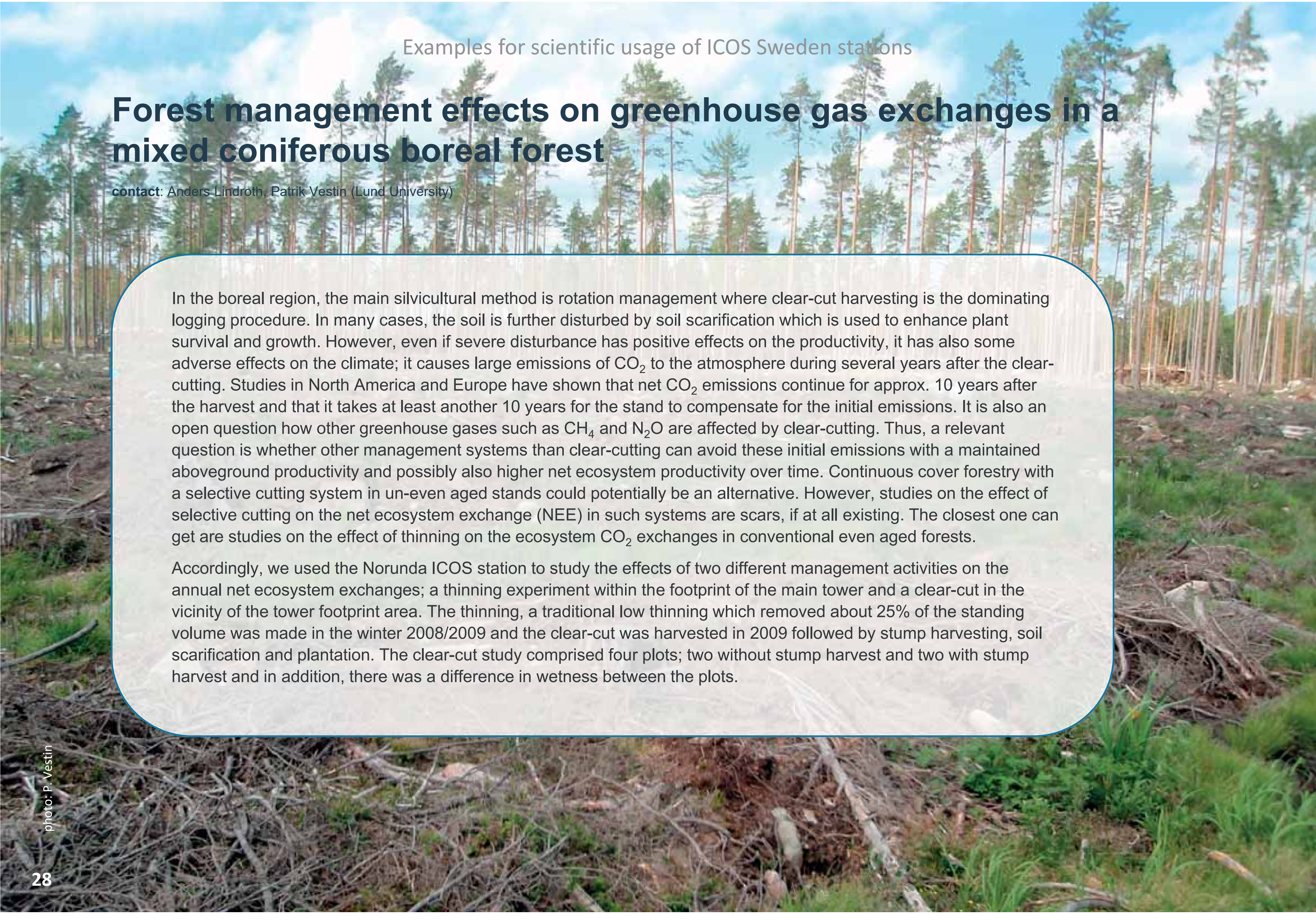
Järveoja, J., M.B. Nilsson, M. Gažovič, P.M. Crill and M. Peichl. 2018. Partitioning of the net CO2 exchange using an automated chamber system reveals plant phenology as key control of production and respiration fluxes in a boreal peatland. Global Change Biology 24, 3436-3451

Nielsen. C. S., N. J. Hasselquist, M. B. Nilsson , M. Öquist, J. Järveoja and M. Peichl, 2019. A Novel Approach for High-Frequency in-situ Quantification of Methane Oxidation in Peatlands. Soil Syst. 3:4

Photo: NN

Forest management effects on greenhouse gas exchanges in a mixed coniferous boreal forest

contact: Anders Lindroth, Patrik Vestin (Lund University)



In the boreal region, the main silvicultural method is rotation management where clear-cut harvesting is the dominating logging procedure. In many cases, the soil is further disturbed by soil scarification which is used to enhance plant survival and growth. However, even if severe disturbance has positive effects on the productivity, it has also some adverse effects on the climate; it causes large emissions of CO_2 to the atmosphere during several years after the clear-cutting. Studies in North America and Europe have shown that net CO_2 emissions continue for approx. 10 years after the harvest and that it takes at least another 10 years for the stand to compensate for the initial emissions. It is also an open question how other greenhouse gases such as CH_4 and N_2O are affected by clear-cutting. Thus, a relevant question is whether other management systems than clear-cutting can avoid these initial emissions with a maintained aboveground productivity and possibly also higher net ecosystem productivity over time. Continuous cover forestry with a selective cutting system in un-even aged stands could potentially be an alternative. However, studies on the effect of selective cutting on the net ecosystem exchange (NEE) in such systems are scars, if at all existing. The closest one can get are studies on the effect of thinning on the ecosystem CO_2 exchanges in conventional even aged forests.

Accordingly, we used the Norunda ICOS station to study the effects of two different management activities on the annual net ecosystem exchanges; a thinning experiment within the footprint of the main tower and a clear-cut in the vicinity of the tower footprint area. The thinning, a traditional low thinning which removed about 25% of the standing volume was made in the winter 2008/2009 and the clear-cut was harvested in 2009 followed by stump harvesting, soil scarification and plantation. The clear-cut study comprised four plots; two without stump harvest and two with stump harvest and in addition, there was a difference in wetness between the plots.

photo: P. Vestin

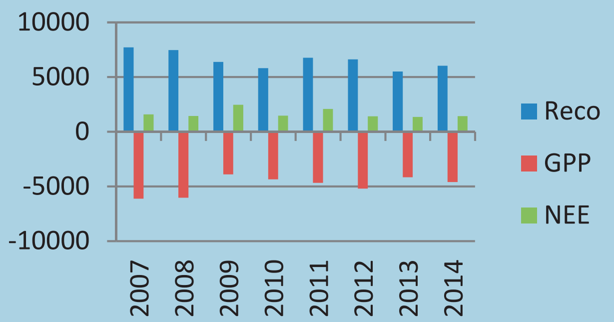


Figure 1. Annual gap filled values for the whole period 2007-2014.

In the thinning study we found that the NEE was reduced with about 40% during the first summer period. The summertime NEE then slowly increased but had not been restored to the pre-thinning values eight years after thinning. There was also a small decrease in summertime ecosystem respiration with a decreasing trend over time. The annual values contrasted with the summertime results since only a minor effect was observed on the annual NEE (Fig. 1). Both ecosystem respiration and gross primary productivity were reduced as an effect of thinning. We explained the different summertime versus annual effects to be caused by the decrease in ecosystem respiration since a lower respiration has a larger impact on the annual NEE, when GPP is low anyhow, then during the summer.

References:
Lindroth, A., J. Holst, M. Heliasz et al., 2018: Effects of low thinning on carbon dioxide fluxes in a mixed hemiboreal forest. Agricultural and Forest Meteorology, 262:59-70.
Vestin, P., Mölder, M., Kljun, N. et al., 2017: Stump harvesting for bioenergy production – short-term effects on carbon dioxide, methane and nitrous oxide fluxes. Submitted to Forest Ecology and Management.

In the clear-cut study the first year annual CO_2 emissions after harvest were remarkably high ranging between 1499 and 1911 $gCO_2\ m^{-2}$ (Fig. 2). There were also CH_4 emissions ranging between 28 and 153 gCO_2-eq m^{-2} during the first year with higher emissions on the wetter plots. No N_2O measurements were made during the first year. During the second year, the both CO_2 and CH_4 emissions decreased somewhat as compared to the initial year. The N_2O emissions during this year ranged between 39 and 220 gCO_2-eq m^{-2}. The total emissions during the first three years ranged between 4217 and 5438 gCO_2-eq, noting that N_2O was not measured during the first year. Our study confirms previous results from clear-cuts and we also conclude that other greenhouse gases than CO_2 are emitted although at lower rates.

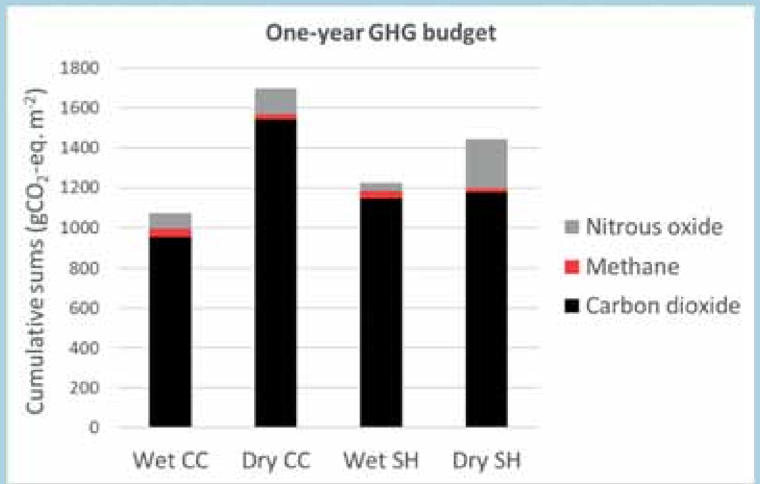
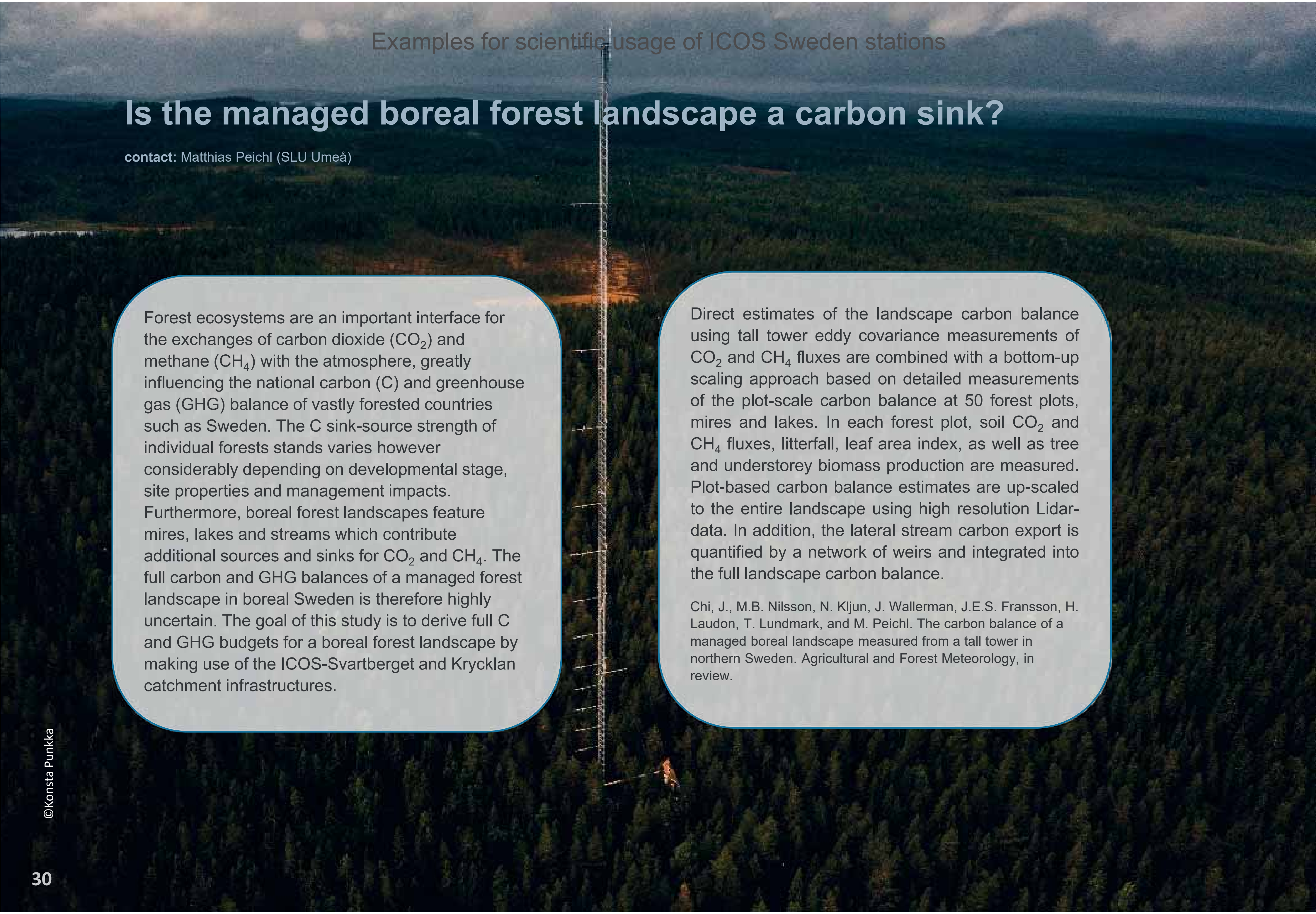


Figure 2. One year full greenhouse gas budgets, expressed as CO_2-equivalents in a 100-year perspective. CC: clear-cut plots, SH: stamp harvested plots.



Is the managed boreal forest landscape a carbon sink?

contact: Matthias Peichl (SLU Umeå)

Forest ecosystems are an important interface for the exchanges of carbon dioxide (CO_2) and methane (CH_4) with the atmosphere, greatly influencing the national carbon (C) and greenhouse gas (GHG) balance of vastly forested countries such as Sweden. The C sink-source strength of individual forests stands varies however considerably depending on developmental stage, site properties and management impacts. Furthermore, boreal forest landscapes feature mires, lakes and streams which contribute additional sources and sinks for CO_2 and CH_4. The full carbon and GHG balances of a managed forest landscape in boreal Sweden is therefore highly uncertain. The goal of this study is to derive full C and GHG budgets for a boreal forest landscape by making use of the ICOS-Svartberget and Krycklan catchment infrastructures.

Direct estimates of the landscape carbon balance using tall tower eddy covariance measurements of CO_2 and CH_4 fluxes are combined with a bottom-up scaling approach based on detailed measurements of the plot-scale carbon balance at 50 forest plots, mires and lakes. In each forest plot, soil CO_2 and CH_4 fluxes, litterfall, leaf area index, as well as tree and understorey biomass production are measured. Plot-based carbon balance estimates are up-scaled to the entire landscape using high resolution Lidar-data. In addition, the lateral stream carbon export is quantified by a network of weirs and integrated into the full landscape carbon balance.

Chi, J., M.B. Nilsson, N. Kljun, J. Wallerman, J.E.S. Fransson, H. Laudon, T. Lundmark, and M. Peichl. The carbon balance of a managed boreal landscape measured from a tall tower in northern Sweden. Agricultural and Forest Meteorology, in review.

Data from the stations at

All raw measurement data from the individual stations will be sent to the respective ICOS RI Thematic Centers, where they will be quality controlled and evaluated following common data handling procedures. The raw data and all analysis results will then be stored in central databases, from where they can be made accessible to end users via the ICOS RI Carbon Portal (data.icos-cp.eu).

This data processing and quality control through the Thematic Centers will start, once a station has finished step 2 in the ICOS labeling process.

Right now, there is ICOS certified data from the **Atmosphere stations** Hyltemossa, Svartberget and Norunda available at the ICOS RI Carbon Portal.

- To download *near real time data* from the Atmosphere stations choose Project: ICOS, Theme: Atmospheric data, Data level: 1
- To download *final quality controlled data* from the Atmosphere stations choose Project: ICOS, Theme: Atmospheric data, Data level: 2

Data from the **Ecosystem stations** can be (at present) downloaded from the Carbon Portal as ICOS Sweden data as level 1 near real time data, which has been machine controlled.

To download data from the ICOS Sweden Ecosystem stations choose Project: ICOS Sweden, Theme: Ecosystem data, Data level: 1

ICOS Sweden ecosystem station data is organized in monthly, resp. annual, thematically grouped files. That means that more than one variable is saved in a file. The files are defined in the Carbon Portal metadata ontology as "Data types" with the extension (ICOS Sweden):

- Ecosystem fluxes time series: ecosystem GHG fluxes
- Ecosystem meteo time series: above canopy meteorological data,
- Ecosystem eco time series: below canopy meteorological data,
- Ecosystem N-level profile time series: gas concentration profile in the air
- Ecosystem N-level T-profile time series: air temperature profile

Citation

Data from ICOS Sweden stations are open under the Creative Commons Attribution 4.0 International License following the FAIR principles. We thus requires a proper reference and citation of the ICOS data, using the exact citation (including the provided doi or pid) as provided by ICOS. We kindly ask you to inform the data providers, traceable through the metadata connected to the provided DOI or PID, when the data is used for publication(s), and to offer them the possibility to comment and/or offer them co-authorship or acknowledgement in the publication when this is justified by the added value of the data for your results. If the main content of a scientific paper is based on ICOS Sweden data, we kindly ask to acknowledge the Swedish Research Council (SRC) who co-finances ICOS Sweden under the Grant No. 2015-06020.

Administrative summary

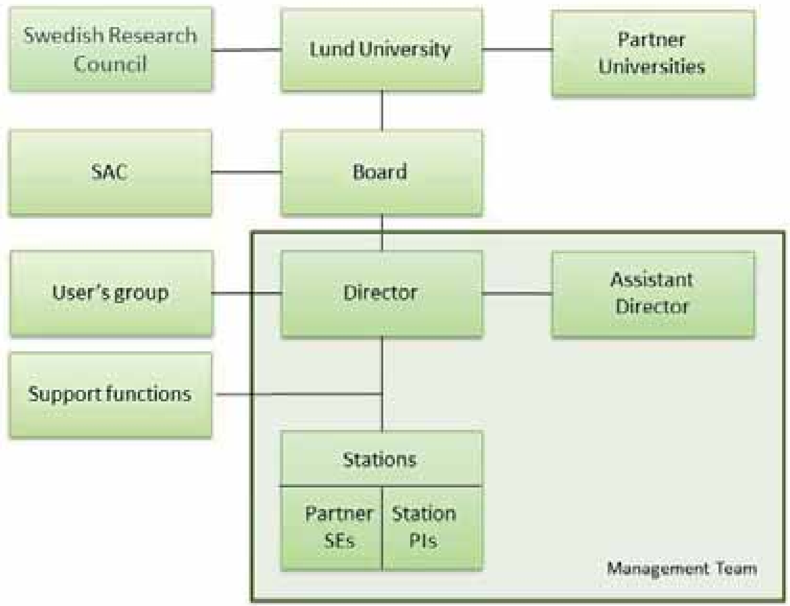
Management and Organization of the infrastructure 2018

ICOS Sweden is a national research infrastructure, financed by the Swedish Research Council under grant No. 2015-06020 and the consortium partners: Lund University (host), University of Gothenburg, Uppsala University, Stockholm University, Swedish University of Agricultural Sciences and Polar Research Secretariat. It is the Swedish node of the international body ICOS RI.

The ICOS Sweden management structure has been built up and consists now – in the beginning of 2019 - of a Board, a Scientific Advisory Committee, and a management team. The management team is led by the Coordinating Director and includes the Science Director, the Station PIs and the Scientific Experts. In 2016, a Scientific and Technical Station Support Module as well as a Communication Officer was added to the Coordination office. The support module is a resource for the stations and the costs for the module are shared between the partners. Below, the different bodies and their duties are described.

The ICOS Sweden Board
The present ICOS Sweden Board members have been selected by the Lund University Vice-Chancellor in agreement with the Swedish Research Council and the Consortium Partners. The members in 2018 were Leif Anderson (Chair; University of Gothenburg), Hannele Hakola, (Finnish Meteorological Institute), Anke Thoss, (Swedish Meteorological and Hydrological Institute), Matthias Lundblad (SLU), Benjamin Smith (Lund University), Ulf Gärdenfors (SLU) and Birgitta Resvik (FORTUM). The Board is responsible for overall strategic and financial monitoring and shall promote development, operation, and management. The Board also decides on the focus and objectives for the collaboration between the different partner organizations that constitute ICOS Sweden. The Board meets the Scientific Advisory Committee (SAC) annually to discuss strategic issues.

The Scientific Advisory Committee (SAC)
The members of the Scientific Advisory Board are Professor Inez Fung (University of California, Berkeley, USA), Professor Yiqi Luo (Northern Arizona University, Flagstaff, USA), Professor Monique Leclerc (University of Georgia, Georgia, USA) and Professor Peter Rayner (University of Melbourne, Australia). The SAC contributes with scientific advice, establishes external links, and acts as ambassadors in general. SAC participates in the annual workshop and, in conjunction to the workshop, meets the Board to discuss strategic issues.



Coordination Office (CO)

The ICOS Sweden Coordination Office is hosted by Lund University. It consists of a Coordinating Director (Maj-Lena Linderson), a Science Director (Janne Rinne), a scientific secretary (Jutta Holst), a communication officer (Susanna Olsson/Ylva van Meeningen), a project assistant (Eva Andersson) and the personnel of the scientific and technical expertise module. This module includes three part time personnel (Meelis Mölder, Jutta Holst and Björn Eriksson). The Coordinating Director decides on all day-to-day scientific, technical, and administrative issues of the research infrastructure. The Coordinating Director also serves as Sweden's national Focal Point to ICOS RI. The Science Director promotes external collaborations and research activities and assists the Coordinating Director in scientific and strategic planning. The CO supervises the activities at the stations and acts as an intermediary between the Board and the rest of the organization. The CO assists the Board in organizing meetings, taking minutes and compiling documents for progress follow up, revisions, and endorsements. Furthermore, the CO coordinates the renewal of applications and agreements as well as the internal communication and common information and outreach activities. The scientific and technical support module delivers support on instrumentation and computer systems, and on data storage and delivery. The modules are resources for the stations and the costs are shared between the partners.

Users' Groups

In the early stage of the buildup of ICOS Sweden, the plan was to set up a Users' Group and a Stakeholder's group. The Users' Group should promote contacts with members of the scientific user community, who are tentatively interested in using research sites and measurement data of the national RI. The Stakeholders' Group aimed at promoting contact with representatives of authorities and organizations that are potentially interested in using the synthesized data products of ICOS RI. Because ICOS RI is not yet fully operational, and ICOS Sweden's activities are just starting, it was decided to join the two contact groups into one single user group open to stakeholders as well as site and data users. At first, the enrollment will be concentrated on scientific users of the data and of the sites. The stakeholder community will be approached once ICOS Sweden is operational and there are data products to display to illustrate the usefulness of the data.

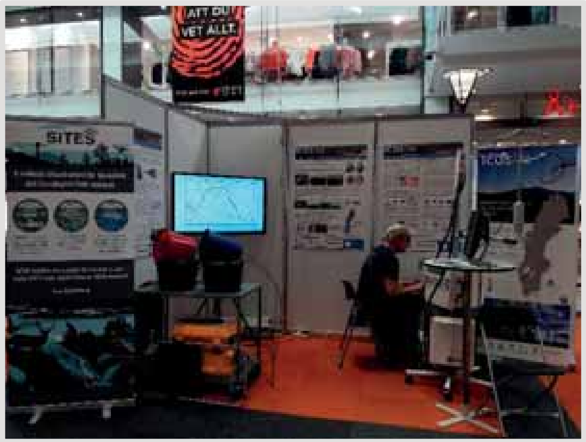
Consortium partners, partner Scientific Experts (SE) and Station Principal Investigators (SPIs)

A Station Principal Investigator (SPI) is appointed for each of the operative ICOS Sweden stations. Responsibilities, tasks, and duties for the SPIs include organizing and managing the activities at their respective measurement station and to be responsible for the data quality checks in conjunction to the data submission to the Thematic Centers. The SPIs participate in the ICOS RI MSAs as representatives of ICOS Sweden and are part of a Station Coordination Group (SCG). The SPIs also promote outreach activities specific for their site e.g. courses and field visits. Each partner also provides ICOS Sweden with a scientific expert (SE) that acts as a contact person between the respective partner and the CO. These experts participate in Management Team meetings in order to be well acquainted with the activities of ICOS Sweden, contribute to application writing, scientific meetings, and to other matters of strategic importance for development of the infrastructure. A partner may appoint the SPI of the measurement station to be its SE. The 2018 list of SPIs includes Mats B. Nilsson (Degerö), Mikaell Ottosson Löfvenius (AS Svartberget), Matthias Peichl (ES Svartberget), Meelis Mölder (Norunda), Anna Rutgersson (Östergarnsholm)Per Weslien (Lanna), Michal Heliasz (Hyltemossa), and Janne Rinne and Patrick Crill (Abisko-Stordalen). The SPIs are at the moment the same persons as the SEs except for Gothenburg University (Lanna) for which Leif Klemedtsson is the SE and for Lund University (Norunda and Hyltemossa) for which Janne Rinne and Natascha Kljun are the SEs.

The management team

The Management Team is made up of the Station Principal Investigators (SPIs) and the scientific experts (SE), as representatives for their respective measurement station and consortium partner. The team coordinates the activities at the different sites, resolves various technical and practical issues, and is a forum for discussions on the management and development of the research infrastructure. The team has regular phone/internet meetings that are complemented by occasional site visits, when needed. They also contribute to applications and reporting, including the strategic development of ICOS Sweden, and act as intermediary between their respective partner and the CO.

Activities during 2018



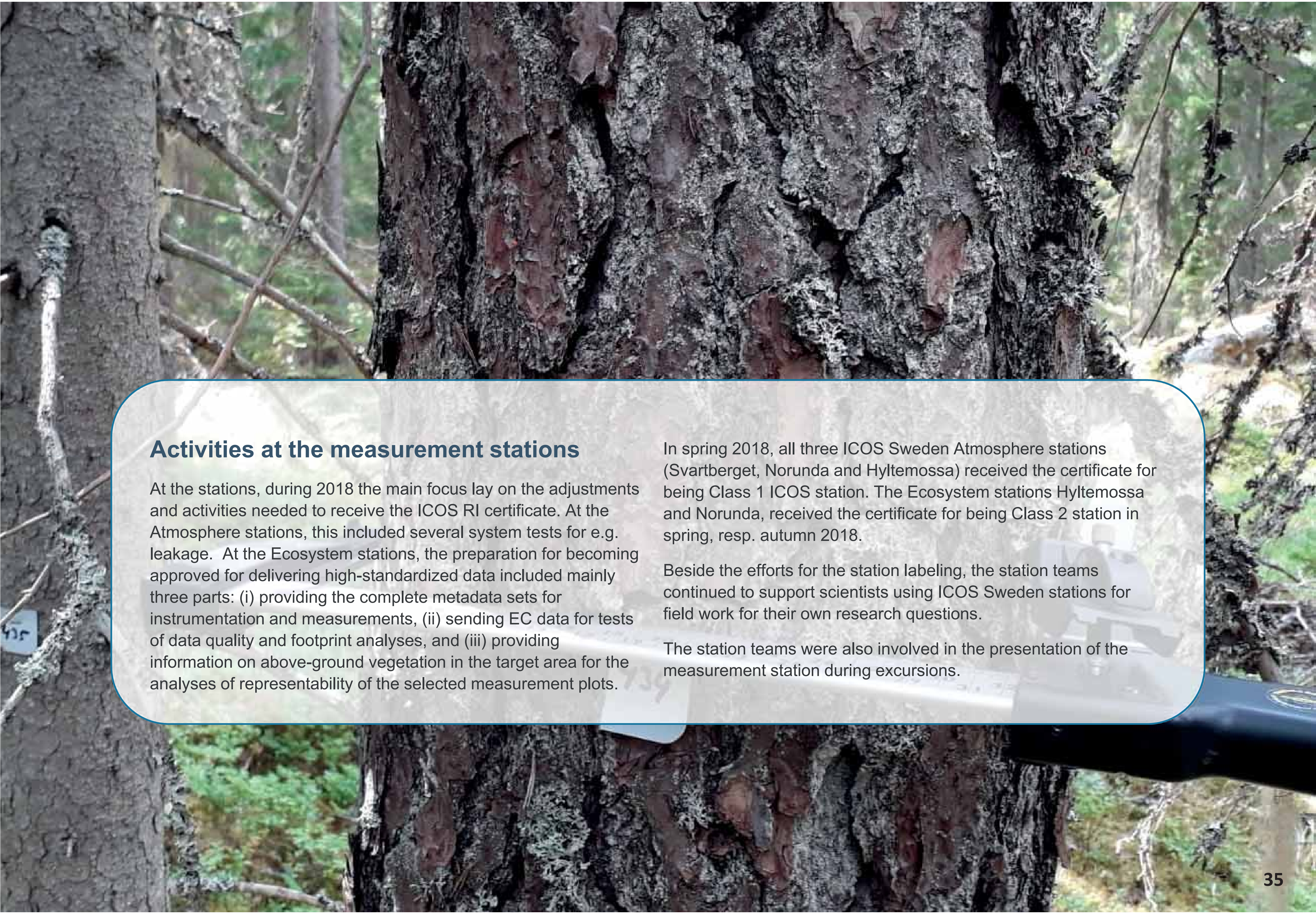
Science Festival, 20-21 April 2018, Gothenburg

Outreach activities

ICOS Sweden continued its outreach activities to scientists and the general public in 2018, e.g. by being present during the Science festival in Gothenburg. Together with the Carbon Portal, ICOS Sweden was interviewed by Swedish Broadcasting teams. The infrastructure and its outcome was presented in talks or posters during various occasions (EGU, ICOS Science Conference, KSLA conference). In June 2018, the Finnish photographer Konsta Punkka visited Svartberget as one stop of the #ICOScapes tour. #ICOScapes aims to raise awareness on the ongoing climate change as well as to highlight the importance of reliable, integrated and standardized GHG measurements in tackling the challenges of a warming world. The photos will be published regularly on the ICOS social media channels. ICOS Sweden continued to encourage applications from ICOS-external researchers aiming at using the RI and its outcomes and to support already ongoing activities.

Other activities

- Monthly WebEx meetings among the research engineers and including station teams and coordination office.
- Face-2-face meeting of the Directors of ICOS Sweden, Board and SAC.
- Face-2-face meeting with the ICOS Sweden Board.
- Taking part in the monthly ICOS RI communication WebEx meetings.
- Taking part in the MSA meetings of the three compartments Atmosphere, Ecosystem and Ocean.
- Janne Rinne has been elected as co-chair of the ecosystem MSA.
- Preparation of the proposal for the coming financing period (2021-2024).
- The CO personnel have collaborated with ICOS RI through focal point meetings and communication meetings and participated in the ICOS ERIC General Assembly meetings. ICOS Sweden personnel have also attended the RINGO project meetings and are involved in collaboration within the WP on lateral fluxes.



Activities at the measurement stations

At the stations, during 2018 the main focus lay on the adjustments and activities needed to receive the ICOS RI certificate. At the Atmosphere stations, this included several system tests for e.g. leakage. At the Ecosystem stations, the preparation for becoming approved for delivering high-standardized data included mainly three parts: (i) providing the complete metadata sets for instrumentation and measurements, (ii) sending EC data for tests of data quality and footprint analyses, and (iii) providing information on above-ground vegetation in the target area for the analyses of representability of the selected measurement plots.

In spring 2018, all three ICOS Sweden Atmosphere stations (Svartberget, Norunda and Hyltemossa) received the certificate for being Class 1 ICOS station. The Ecosystem stations Hyltemossa and Norunda, received the certificate for being Class 2 station in spring, resp. autumn 2018.

Beside the efforts for the station labeling, the station teams continued to support scientists using ICOS Sweden stations for field work for their own research questions.

The station teams were also involved in the presentation of the measurement station during excursions.

Financial outcome 2018

A summary of the financial outcomes for 2018 for all sites are given in the table to the right. It should be noted that this is a liquidity budget, using incomes and expenses and no depreciation costs, which means that the difference between the total incomes and total expenses represent the amounts available. The closing balance corresponds to the accumulated amount available since 2010, following the contributions by SRC and the partners in the consortium agreement. It thus includes the funding for 2019 and 2020.

The outcome for 2018 follows the budget fairly well. LU has slightly higher salary costs, due to increased personnel at the site in order to fulfil the labeling requirements. SLU has lower salary costs, mainly due to the delay when replacing personnel that left for other work. The closing balance for GU is negative. This will be met by decreasing the costs during 2019-2020. Some investments planned at the atmosphere sites were delayed until 2019.

The remaining assets in the closing balance are reserved to cover costs in the annual balances 2019-2020 including remaining investments to fulfil the requirements for the atmospheric sites.

Financial outcomes 2018 for each partner and in total (kSEK). For acronyms, see App. 3.

	LU	SLU	GU	UU	Polar	SU	Total
Incomes							
Initial balance	5,769	2,170	346	1,007	301	122	9,715
Incomes SRC	3,184	1,896	970	770	180	0	7,000
Co-financing	4,516	3,330	1,300	1,301	335	179	10,961
Sum (SRC+Co-financing)	*7,700*	*5,226*	*2,270*	*2,071*	*515*	*179*	*17,961*
Costs							
Salaries	4,901	1,816	1,002	914	490	179	9,303
Consumables	1,506	1,368	784	422	134	0	4,214
Travels	341	159	0	76	14	13	603
OH	2,229	686	854	503	153	35	4,461
Technical Support (incl OH)	477	483	235	165	0	0	1,360
Investments	495	184	29	0	24	0	732
Sum (Costs)	*9,949*	*4,696*	*2,905*	*2,081*	*816*	*228*	*20,674*
Difference	-2,249	531	-635	-9	-301	-49	-2,712
Closing balance	3,520	2,700	-289	998	0	73	7,002

Appendix 1: List of personnel during 2018

Total amount of FTEs: 14

Coordination Office:
Maj-Lena Linderson, coordinating director, 50%
Janne Rinne, science director, 20%
Jutta Holst, scientific secretary 20%, scientific and technical station support, 80%
Meelis Mölder, scientific and technical station support, 70%
Susanna Olsson, communication officer, Apr-Sep, 50%
Ylva van Meeningen, communication officer, Jan-May, 50-100%
Wilhelm Dubber, Sep-Dec, 50%
Eva Andersson, project assistant, 10%

Measurement stations:
Abisko-Stordalen:
50% split into Robert Holden, research engineer, Jan-Mar
Erik Lundin, research engineer and
Niklas Rakos, research engineer
Dagmar Egelkraut, Project Employed Expert, May- Jul, 100%
Janne Rinne, station PI and SE, 10%
Patrick Crill, station PI and SE, 10%

Degerö and Svartberget:
Per Marklund, 100%
Eric Larmanou, research engineer, Jan-Sep, 100%
Pernilla Löfvenius, research engineer, 50%
Guiseppe de Simon, research engineer, Jan-Sep, 50%
Guiseppe de Simon, research engineer, Oct-Dec, 100%
Mikaell Ottosson Löfvenius, station PI and SE, 20 %
Mats Nilsson, station PI and SE, 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%
Erik Nilsson, research engineer, 45%
Monica Mårtensson, research engineer, 5%

Lanna:
Per Weslien, Station PI, research engineer, 75%
Bengt Liljeblad, research engineer, 25%
Leif Klemedtsson, SE, 30%

Hyltemossa:
Tobias Biermann, research engineer, station manager, 100%
Michal Heliasz, station PI, research engineer, 100%
Thomas Holst, research engineer, 20%
Janne Rinne, SE

Appendix 2: List of station parameters 2018

Table 2.1. ICOS Sweden Ecosystem stations 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

Ecosystem stations		Hyltemossa (SE-Htm)	Norunda (SE-Nor)	Svartberget (SE-Svb)	Lanna (SE-Lnn)	Degerö (SE-Deg)	Abisko-Stordalen (SE-Sto)
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
	CO_2 profile	14 levels1	14 levels1	14 levels1	5 levels	5 levels	5 levels
	H_2O profile	14 levels	14 levels	14 levels	5 levels	5 levels	5 levels
	CH_4 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

Ecosystem stations		Hyltemossa (SE-Htm)	Norunda (SE-Nor)	Svartberget (SE-Svb)	Lanna (SE-Lnn)	Degerö (SE-Deg)	Abisko-Stordalen (SE-Sto)
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 (hemispherical pictures)	6/year	6/year	6/year	-	-	-
	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 Atmospheric stations 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	Mikaell Ottosson Löfvenius, 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	Atmospheric Thematic Center
AS	Atmosphere station
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
HO	Head office
ICOS RI	Integrated Carbon Observation System Research Infrastructure
ICOS PP	ICOS Planning Project (sometimes also Preparatory Phase)
ISIC	ICOS Stakeholder Interim Council
OS	Ocean station
OTC	Oceanic Thematic Center

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
SU	Stockholm University
SLU	Swedish University of Agricultural Sciences
PFS	Swedish Polar Research Secretariat

Other infrastructures and organizations

ACTRIS	Aerosols, Clouds, and Trace gases Research Infrastructure network (http://www.actris.net)
ANAEE	Analysis and Experimentation on Ecosystems (www.anaee.com)
GMES	Global Monitoring for Environment and Security (now called Copernicus, http://www.copernicus.eu)
INTERACT	International Network for Research and Monitoring in the Arctic (http://www.eu-interact.org)
WCRP	World Climate Research Program (http://www.wcrp-climate.org)
SITES	Swedish Infrastructure for Ecosystem Research (http://www.fieldsites.se/)

Other

CWG	contract working group
GHG	greenhouse gas
SMHI	Swedish Meteorological and Hydrological Institute
SRC	Swedish Research Council (in Swedish VR – Vetenskapsrådet)

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ICOS National Network Sweden