ICOS INTEGRATED CARBON OBSERVATION SYSTEM

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The 3rd ICOS Science Conference

BOOK OF ABSTRACTS

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Contents

ICOS in Short

The Integrated Carbon Observation System, ICOS is a distributed European-wide research infrastructure producing high-precision data on greenhouse gas concentrations in the atmosphere, as well as on carbon fluxes between the atmosphere, earth and oceans.

This is important because globally the amount of greenhouse gases in the atmosphere rises constantly, causing the climate change. The greenhouse gases flux between the ecosystems, atmosphere and oceans, and are transported in the atmosphere even thousands of kilometres, for example, from densely populated areas to the arctic. ICOS provides standardised and open data from over 130 measurement stations across 12 European countries.

ICOS data is used by scientists who seek to understand this Earth System and by various governmental bodies and international organisations that need science-based and relevant information on greenhouse gases in their decision making, and in efforts to mitigate the consequences of climate change.

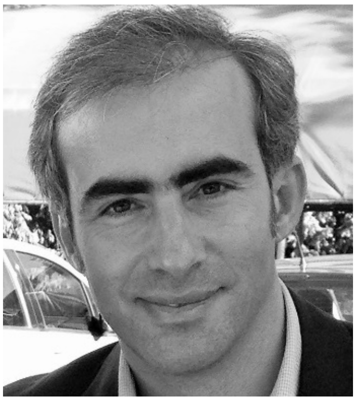
ICOS consists of more than 500 scientists, who participate in ICOS related work and operations. These scientists, both in the current member countries and beyond, form the ICOS community. They design, build and operate ICOS stations, but even more importantly, process and use the ICOS data while fitting complex models on it. They publish scientific papers, participate in workshops and conferences, and develop new measurement methods.

The community, as ICOS itself, has three fields; ecosystem, atmosphere, and ocean. Each of these also has strong connections to colleagues and operators outside ICOS. At the moment ICOS community includes over 70 scientific organisations, renown universities or institutes - many of which are leaders in their fields.

The biannual ICOS Science Conference gathers more than 300 scientists to discuss the scientific topics around greenhouse gas measurement and climate change. The themes of the conference vary from purely scientific sessions to ones related to the Paris Agreement and other policy making.

Presentation of key note and plenary speakers

Giacomo Grassi



Giacomo Grassi has been acting as a Senior Scientific Officer at the Joint Research Centre (JRC) of the European Commission since 2005. Dr Grassi holds a PhD in Forest Ecology. He also leads the group on 'Land Use, Land Use Change and Forestry' (LULUCF) within the Directorate on Sustainable Resources, which is dealing with the estimation of CO_2 fluxes from managed terrestrial ecosystems – mainly forests – and their reporting to the UN Framework Convention on Climate Change (UNFCCC).

Dr Grassi is focused on coordinating the LULUCF sector of the EU greenhouse gas inventory and the modeling of forest carbon dynamics at EU level using the Carbon Budget Model. He provides scientific support in the design of policies at EU level (e.g. the forest reference levels under the post-2020 LULUCF Regulation) and under the Paris Agreement. Dr Grassi is an expert reviewer of LULUCF GHG inventories for the UNFCCC and a lead author of several IPCC reports, such as "2013 Supplementary Guidance under the Kyoto Protocol", "Methodological Refinement of the 2006 Guidelines for GHG inventories" and "Special Report on Climate Change and Land". He has published 50 papers in peer-reviewed journals, mostly focused on the carbon balance and the mitigation potential of forest ecosystems.

Giacomo Grassi gives a keynote on Tue 11th Sep on "Bridging gaps between policy-making and science: the case of forest GHG estimates".

Joanna Post

Joanna Post has been working with the United Nations Framework Convention on Climate Change (UNFCCC) secretariat since 2014. Since 2015 she has been based in the Science and Review Unit of the Adaptation Programme where she supports negotiations under the UNFCCC and its Paris Agreement on research and systematic observation. She is a programme officer working on issues related to Earth observation, research, climate services and developing dialogue at the science/policy interface. She is also the thematic focal point on oceans and adaptation.

Prior to joining the secretariat, Dr. Post managed a number of national and international scientific research and educational programmes and projects in both the UK and Germany. She holds a Ph.D. in environmental biochemistry from the University of Newcastle Upon Tyne, UK.

Joanna Post gives a keynote on Tue 11th Sep on "The Paris Agreement and implications for Earth Observation science".

Dennis Baldocchi

Dennis Baldocchi is a professor of biometeorology at the University of California, Berkeley. He and his research group conduct experimental and theoretical studies on the physical, biological and chemical control of trace gas exchange between vegetation and the atmosphere. Goals of work are to predict fluxes of carbon, water and energy, mechanistically, everywhere, all of the timeLines of inquiry have been along understanding how fluxes of mass and energy between ecosystems and the atmosphere vary along a spectrum of time and space scales in accordance with structure, function, weather and climate and management. Methods used include use of the eddy covariance method tomeasure net fluxes of mass and energy across the atmosphere-ecosystem interface. Data are interpreted and distilled through the lens of the CANVEG family of models, physiological measurements at the leaf scale and flux measurements across the soil-atmosphere interface.

His current work focuses on: 1) the roles of management and ecological restoration on greenhouse gas fluxes of crops and wetlands; 2) the impact of weather, climate trends and variability, physiological stress, and structure and function on the greenhouse gas fluxes of savanna woodlands and annual grasslands; and 3) the upscaling and interpretation of fluxes across climatic and ecological gradients with the AmeriFlux and FLUXNET networks.

Prof. Baldocchi has been principal investigator of Fluxnet since 1997 and is co-investigator of Ameriflux. He is a fellow of the American Geophysical Union, recipient of the American Meteorological Society Award for Outstanding Achievement in Biometeorology and a Clarivate Analytics Highly Cited Scientist over multiple years in Agricultural Science and once in Ecology/Environment.

He served as Editor in Chief of the Journal of Geophysical Research, Biogeoscience, as subject editor of Global Change Biology and on the editorial boards of numerous other journals. He has served on numerous science advisory panels including the Max Planck Institute for Biogeochemistry and the Department of Energy, Biological and Environmental Research Division.

Dennis Baldocchi gives a keynote on Wed 12th Sep on "Viewing ICOS in a global context: lessons learned from the global network, FLUXNET".

Maciej Telszewski

Maciej Telszewski holds a PhD in Marine Biogeochemistry from the University of East Anglia (Norwich, UK), where he worked with surface ocean carbon data to develop an efficient neural network algorithm allowing basin scale mapping of this parameter in the North Atlantic. He then moved to Japan, where he joined a research group at the National Institute for Environmental Studies (Tsukuba) to further improve the statistical computing approach. His work resulted in successful mapping of surface carbon and nutrients fields in the North Pacific accompanied by fluxes estimates included in the RECCAP synthesis.

Throughout his research carrier he was actively involved in field campaigns, contributing surface measurements to the Surface Ocean CO2 Observing Network (SOCONET) and ocean interior measurements to the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP). He contributed research outputs to major projects like EU CARBOOCEAN IP (2005-2009) focused on marine carbon sources and sinks assessment and EU CARBOCHANGE (2011-2015) focused on the ocean's quantitative role in the uptake of carbon under changing climate conditions. In 2011 Maciej joined the Intergovernmental Oceanographic Commission of UNESCO (Paris, France) initially as a Deputy Director of the International Ocean Carbon Coordination Project (IOCCP) and since mid-2012 as IOCCP's Project Director (and Global Ocean Observing System (GOOS) Biogeochemistry Expert Panel Executive Officer). In this role he coordinates the highly diverse set of ocean carbon and biogeochemistry activities through extensive collaboration and dialogue with the scientific community via national and international organizations, scientific steering committees, scientific workshops, and expert meetings.

Specifically, he is tasked to:

Organize and implement targeted workshops to promote the development of a global network of marine biogeochemistry observations, including workshops to reach agreements on global strategies, data sharing practices, and best practices and standards, and to ensure that data from individual programs are comparable globally.

Facilitate data collection, management, data product development, and archival of ocean carbon and related data. During the past decade IOCCP played a fundamental role in development of the Surface Ocean Carbon Atlas (SOCAT), and the Global Ocean Data Analysis Project (GLODAPv2).

Maintain an international directory of ocean carbon activities through the development and maintenance of web-based compilations and syntheses of ocean carbon observations and research activities, and through e-mail and web-based newsletters and other publications.

Work with national and international research and observation programs to promote and document the development and status of a sustained marine biogeochemistry observing system in the framework of the Global Ocean Observing System.

Liaise with atmospheric and terrestrial carbon programs to promote the integration of ocean carbon into earth system studies and global integrated observations (e.g. Integrated Carbon Observation System (ICOS)).

Maciej Telszewski gives a keynote on Wed 12th Sep on "Viewing ICOS in a global context from coordinated ocean observations, through high quality data products to global ocean carbon fields and fluxes".

Philippe Ciais

Philippe Ciais has received a PhD in 1991 for a topic titled "Holocene climate record of Antarctic ice cores".In 1992, Dr Ciais was a post-doctoral fellow at the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado, where he investigated how 3C and 18O isotopes in atmospheric CO2 can be used to constrain terrestrial carbon fluxes. He also designed the first three-dimensional simulation model of 8O in CO2, an isotopic tracer of the water cycle coupled with CO2 uptake by plant photosynthesis.

From 2005 to 2013, Philippe Ciais devoted his time to the coordination of the preparation of the Integrated Carbon Observation System (ICOS), being part of the national and European auditions, technical preparation work, and the negotiation of the governance and funding leverage. At that time, Philippe Ciais also acted as a co-chair of the Group on Earth Observations (GEO) task force on integrated carbon observations.

In addition, Dr Ciais ha co-chaired of the Global Carbon Project in 2009-14. He also acted as a Convening Lead Author of the IPCC Working Group 1, for the Carbon Cycle chapter of the 5th IPCC Assessment Report.

Dr Ciais' research activities during the last twenty years has mainly included the relationship between ecosystem CO2 fluxes and climate, combining terrestrial biosphere models with satellite and eddy-covariance observations. By the age of 52, Philippe Ciais has contributed to more than 600 publications in Aranking journals over the past 17 years. He was ranked as the most productive scientific author in the field of climate change, and among the authors who contributed to 5 of the 100 most influential papers in this field.

Philippe Ciais gives a keynote on Thu 13th Sep on "The global carbon balance of forests based on flux towers and forest age data".

Adrian Leip

Adrian Leip is a Senior Scientific Officer at the Joint Research Centre (JRC) of the European Commission since 2001. Dr Leip holds a PhD in Geo-ecology (University of Bayreuth, Germany). His work focuses modelling of emissions and mitigation options of GHGs and reactive nitrogen using process-based and agro-economic models, life cycle assessment including nitrogen and carbon footprint analyses; assessment of food systems in Europe; development of sustainablity indicators.

Within the Food Security Unit of the Directorate on Sustainable Resources, he leads the activities related to emissions of greenhouse gases from agricultural sources and nitrogen flows in agricultural systems and beyond (national nitrogen budgets). This includes also the work within the EU GHG inventory system, where he is responsible for the sector agriculture, in particular QA/QC of agricultural emission estimates, including methodological assessments of uncertainties in GHG emission estimates. Dr Leip is co-chair of the Expert Panel on Nitrogen and Food under the Task Force on Reactive Nitrogen (UN-ECE LRTAP Convention) and currently chairs the Technical Advisory Group on Nutrient Cycles Assessment of the Livestock Environmental Assessment and Performance Partnership (LEAP, FAO). He is a lead author of the IPCC "Methodological Refinement of the 2006 Guidelines for GHG inventories" for the agriculture sector and the IPCC "6th Assessment Report – WG-III Mitigation". Dr Leip has published over 50 papers in peer-reviewed journals mainly on the nitrogen cycle and agricultural GHG emissions.

Adrian Leip gives a keynote on Thu 13th Sep on "Bottom-up and top-down methods in national GHG emission reporting".

Plenary Speakers

Alex Vermeulen

Alex Vermeulen is director of the ICOS Carbon Portal. He has a strong background in (micro)meteorology, air quality modelling, observation techniques and data acquisition and ecosystem science. He has authored or co-authored more than 60 peer-reviewed scientific publications (current H-index 24). He has been involved as PI or coordinator in international cooperation projects since 1994. He started as junior scientist on a project on ammonia deposition and acidification research at ECN (Energy Research Center of the Netherlands). Since 1990 he worked in climate research in the field of GHG emission and concentration measurements and transport modelling. He has been project leader since 1994 and has been assistant group leader (~20 people) from 2005-2012. Since June 2014 he is Director of the Carbon Portal, leading a group of 12 scientists and technicians at Lund and Wageningen University. As ECN project leader he participated in European projects like European Methane (FP4), AEROCARB, RECAB (FP5), CarboEurope-IP, IMECC, GEOMON, EuroHydros, GHG-Europe, and ACTRIS (FP7). He coordinated the CHIOTTO (FP5, RTD, 5 M€, 10 partners) and the InGOS (FP7, IA, 12 M€, 38 partners) project. Currently he is involved as PI and task leader in the H2020 projects EUDAT2020, ENVRIplus and RINGO. He is chair of the WMO GAW Greenhouse Gas Scientific Advisory Board. He also initiated, acquired and coordinated the ESF research networking program TTORCH. Besides the activities on climate change research he worked in the fields of local air pollution, specifically measurement and modelling of highway dispersion; dry deposition flux measurements and high-resolution modelling of deposition loads. He was Focal Point for ICOS-NL and coordinated the ECN observations at Cabauw tall tower from 2000-2014. At ECN he was project leader for several big national projects on climate change in the field of GHG exchange and coordinator of the Dutch network on GHG observation in the national ME-2 project.

Alex Vermeulen gives a plenary talk on Tue 11th Sep on “The services and products provided by ICOS”.

Róisín Commane

Prof. Roisin Commane is an Assistant Professor in the Dept. of Earth and Environmental Sciences at Columbia University in New York City and the Lamont-Doherty Earth Observatory in Palisades, NY. Her work combines aircraft, tall tower and eddy flux measurements, with process based models to understand the atmospheric budget of a range of trace gases, with a focus on carbon in the Arctic. She is co-lead of the NASA Arctic and Boreal Vulnerability Experiment (ABoVE) Carbon Dynamics Working Group and a member of the Science Leadership Group of the North American Carbon Project (NACP). As part of NASA's Atmospheric Tomography Mission (ATom), she recently made airborne measurements of CO2, CH4, N2O and CO on the NASA DC8 on flights in the remote atmosphere above the Pacific and Atlantic oceans 2016-2018.

Before moving to Columbia University in July 2018, Roisin was a Research Associate at Harvard University, where she also developed quantum cascade laser spectrometers to measure fluxes of carbonyl sulfide (OCS) in collaboration with Aerodyne Research Inc. She deployed these instruments at a mid-latitude forest

(Harvard Forest) for three years and found OCS fluxes were a good indicator of ecosystem scale stomatal conductance. Roisin obtained her PhD in Atmospheric Chemistry from the University of Leeds, where she studied oxidation of trace gases above tropical forests and in the marine and arctic boundary layers, using Laser-induced Fluorescence techniques.

Róisín Commane gives a plenary talk on Wednesday 12th Sep on "Data-constrained annual carbon fluxes for Arctic and Boreal ecosystems".

Mathew Williams

Mathew Williams is Chair of Global Change Ecology at the University of Edinburgh. His research is on quantifying and understanding the terrestrial carbon cycle and its links to global change. He has studied the interactions of plant and soil processes across environmental and biodiversity gradients from the tropics to the Arctic. He uses process based modelling and data assimilation methods to extract information from detailed ecosystem measurements on feedback processes between soil, vegetation and the atmosphere, over timescales from days to years. Linking to remote sensing data, his group uses models to upscale process information to investigate landscape processes. He focuses particularly on issues relating to the drought sensitivity of forests and croplands, the role of disturbance (fire or anthropogenic) on forest biomass, and the sensitivity of Arctic ecosystems to warming. Understanding and simulating the non-steady state behaviour of ecosystems is a current focal interest. Mathew is a PI for the UK National Centre for Earth Observation, Director of the NERC Field Spectroscopy Facility, a member of NERC Science Board, and on the science team for the ESA Earth Explorer Biomass Mission.

Mathew Williams gives a plenary talk on Wednesday 12th Sep on **"**Constraining terrestrial carbon balance through assimilation of remotely sensed biomass data into CARDAMOM".

Stefan Schwietzke

Dr. Schwietzke is a Research Scientist at the National Oceanographic and Atmospheric Administration's Global Monitoring Division and the University of Colorado's Cooperative Institute for Research in Environmental Sciences in Boulder, CO. His research focuses on methane emissions from different sources at different scales: from local to global, which requires the application of different quantification methods in terms of measurement platforms and data analysis. In addition to academic positions, Dr. Schwietzke has worked in large corporations and business consulting. He holds B.S. and M.S. degrees in Mechanical Engineering and Technology Management, respectively, from the University of Stuttgart, Germany, and a Ph.D. in Engineering and Public Policy from Carnegie Mellon University.

Stefan Schwietzke gives a plenary talk on Wednesday 12th Sep on "Recent developments in using isotopic measurements for constraining methane sources and sinks".

Ana Bastos

Ana Bastos obtained her PhD in Geophysical and Geoinformation Science in 2015, in which she studied the links between atmospheric and ocean variability and anomalies in the terrestrial carbon cycle, combining satellite-, measurement- and model-based estimates of terrestrial CO2 fluxes and ecosystem productivity. She worked as a Post-Doc at the Laboratoire des Sciences du Climat et de l'Environnement (LSCE, France) where she focused on understanding the gap in the CO2 budget estimates during the 20th century, particularly the contribution of inter-annual to decadal variability in climate and changes in land-use to the uncertainty in the terrestrial global CO2 budget. Recently, A.B. moved to the Geography Department of the Ludwig-Maximilians University in Munich where she intends to extend her focus to the impact of natural disturbances and human activities in terrestrial C-stocks.

A.B. is currently involved in several projects aiming at improving estimates of ecosystem productivity and biomass stocks and in a project funded by the European Space Agency Climate Change Initiative to support the second phase of the "REgional Carbon Cycle Assessment and Processes (RECCAP-2) promoted by the Global Carbon Project.

Ana Bastos gives a plenary talk on Thursday on Thu 13th Sep on "Connecting global and regional carbon budgets to support policy-making".

Holger Lange

Holger Lange received a Ph.D. in theoretical physics and then moved to environmental science, in particular modelling of forested ecosystems. In 1999, he became an associate professor in Ecological Modelling at the University of Bayreuth, Germany, and since 2009, he is also Head of the Department for Terrestrial Ecology at the Norwegian Institute for Bioeconomy Research (Nibio) in Ås, Norway. Scientific interests include the terrestrial carbon cycle, climate impact modelling, remote sensing, time series analysis and nonlinear statistics. He is the PI of the ICOS ecosystem station NO-Hur in Hurdal, Southeast Norway."

Holger Lange gives a plenary talk on Thursday 13th Sep on **"**Combining remote sensing earth observations and in situ networks: detection of extreme events and optimal network size and design".

Jocelyn Turnbull

Jocelyns' research is focused on the atmospheric carbon cycle, with a particular interest in the source and fate fossil fuel CO2 emissions. She is investigating fossil fuel emissions at scales from individual point sources, to urban areas, to regions. Some of her current research projects are: the Indianapolis Flux Project (INFLUX), where we aim to develop and assess methods for determining urban scale emissions; Auckland's Carbon Emissions, whereby we investigate not only the urban emissions, but the extent to which the urban ecology mitigates those emissions; Southern Ocean atmospheric radiocarbon, which uses radiocarbon measurements to investigate the mechanisms of Southern Ocean carbon exchange.

Jocelyn Turnbull gives a plenary talk on Thursday 13th Sep on "Quantification of urban CO_2 emissions in Indianapolis and Auckland".

Abstracts of the key note and plenary speakers*

*To be updated continuously upon receiving abstract texts

Bridging gaps between policy-making and science: the case of forest GHG estimates

Giacomo Grassi, European Commission, Joint Research Centre

Achieving the long-term temperature goal of the Paris Agreement (PA) requires more confidence in GHG estimates. What is not measured with confidence cannot be managed. To this regard, the PA includes an Enhanced Transparency Framework, to track countries' progress towards achieving their individual targets, and a periodic Global Stocktake to assess the countries' collective progress towards the long-term goals of the PA based on the best available science. This is a challenge and an opportunity for the scientific community. The challenge involves supporting country GHG inventories, which are at the basis of policy making, including through regular reviews of the latest science and methods and with independent verification of countries' GHG estimates. The opportunity is to improve the scientific understanding and to help build confidence on GHG estimates and their trends, therefore enabling to achieve the PA's ambitious goal.

The talk will assess the challenges and opportunities associated to the ≈3 $GtCO_2e$/y discrepancy in current global forest GHG estimates between country reports and scientific studies (e.g. IPCC AR5). This discrepancy is largely explained by conceptual differences in estimating the "anthropogenic" forest sinks between the GHG inventories community and the scientific community. While recognizing differences in scopes between these communities, reconciling large conceptual gaps in estimates is a necessity, because the Global Stocktake will be based on both country reports and IPCC reports. Ultimately, assessing the "balance between anthropogenic GHG emissions by sources and removals by sinks in the second half of this century", needed to reach the temperature goal of the PA, requires countries and science to speak the same language on what is "anthropogenic". The proposed way forward requires improving mutual understanding and cooperation between the GHG inventory compilers and the scientific community.

The Paris Agreement and implications for Earth Observation science

Dr Joanna Post, United Nations, Climate Change Secretariat

The Paris Agreement is an historic, global, balanced and ambitious agreement. It set long-term goals to keep global temperature rise this century well below 2°C above preindustrial levels and pursue efforts to limit the temperature increase to 1.5°C, to strengthen the ability of countries to deal with the impacts of climate change and to develop sustainably. The Paris Agreement requires all Parties to put forward their best efforts through nationally determined contributions (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts on progress and a regular and comprehensive global stocktake to inform national contributions and enhance international cooperation.

Earth observation is the gateway to inform scientific planning and report on action taken on the Paris Agreement as set by policy makers. Successful implementation of the Paris Agreement requires observation information regarding: greenhouse gas concentrations to inform national action; science for services to support countries, and other stakeholders, access relevant and understandable information to plan and assess climate risk and adaptation; and indicators to inform global stocktaking and support countries' ambitions in limiting global average temperature.

This presentation will discuss the most recent developments in the UNFCCC negotiations and their implications as well as opportunities for the Earth Observation Community.

The services and products provided by ICOS

Alex Vermeulen, the ICOS CP team & the ICOS RI community

ICOS is the European Integrated Carbon Observing System that performs standardized, long term, high precision and high quality observations on the Carbon Cycle and Greenhouse Gas budgets and their perturbations. All services and products of ICOS revolve around this primary objective. Since its conception around 2006 and its legal establishment as ICOS ERIC in 2015, ICOS has been working towards becoming an operational network that is extremely relevant to Climate Change science and policies. The three domains Atmosphere, Ocean and Ecosystem consist of networks of currently total 131 highly standardized stations, organised as 12 national networks. Central facilities for each of the 3 domains and the Central Calibration Laboratories provide services that ensure the quality of the observations and process the observational data from the raw data towards quality controlled Near Real-Time and final data products, working in close cooperation with the assemblies of the station managers. All ICOS data products are made available through the central ICOS data portal, the Carbon Portal, that together with ICOS Head Office forms the ICOS ERIC.

This presentation will inform you of the progress of the operational network, and the current and planned services and data products that ICOS delivers to its users. Users are of course ICOS station managers and technicians, scientific users from inside and outside the ICOS community; but also citizen scientists, students, the general public and policy makers are important target users. We foresee that ICOS data will play an important role to inform society on the progress in mitigation of Climate Change due to emission reductions of greenhouse gases, for example in the framework of the Paris agreement. Also ICOS data will provide important insights in the development of the natural and managed land related GHG fluxes under the influence of ongoing climate change that feedbacks into the Earth System. International efforts like WMO, GEO, UNFCCC and IPCC are important channels for the ICOS data and services.

The Carbon Portal has been designed as FAIR data system avant la lettre. This to ensure that all ICOS data is made available for open access, can be found easily, is fully traceable and complete with all relevant associated descriptive metadata that adheres to the community standards. This will ensure that the data can be re-used for all possible applications any time in the future and is interoperable with other (environmental) data and services. The Carbon Portal is also built as community platform for working on elaborated data products that use the ICOS data together with other data, using sophisticated computer models, and again publishing these scientific results with high added value to an ever-increasing user base. Some initial examples of this kind of elaborated data and services will be shown as well.

Viewing ICOS In a Global Context: Lessons Learned from the Global Network, FLUXNET

Dennis Baldocchi, University of California, Berkeley

Regional networks of eddy covariance flux towers have been operating in Europe, North America and parts of Asia for nearly 20 years. Hence, we have collected thousands of site-years of ecosystem-scale carbon, water and energy flux data from hundreds of sites across a broad swath of ecological and climate space. The overarching goal of this flux work is to be able to 'assess fluxes everywhere and all of the time.'

One of the key intellectual attributes of mining relationships from a network of flux data is that we can define how the metabolism of ecosystems responds to environmental drivers at ecosystem time and space scales. In other words, with flux data we can quantify a nearly continuous response functions, identify non-linear responses and scale-emergent processes; these are attributes that are not well defined with ecosystem manipulation experiments, as they are associated with a limited number of samples and treatments that are of a relatively small area.

In this lecture we give an overview of some of the key lessons we have learned by working together, sharing data and producing flux sums on annual to decadal time scales. Some lessons pertain to constraints among gross and net carbon fluxes, water and energy. Other lessons pertain to the timing and length of physiological activity, as defined by phenology. And, other lessons relate to the acclimation of basal rates of soil respiration and optimal rates of photosynthesis to temperature and the response of whole ecosystem metabolism to variations in soil moisture.

Among the key lessons we find are a tight linkage between annual sums of ecosystem photosynthesis and respiration ($r^2 > 0.85$; slope ~ 0.86) and year to year variability; environmental conditions that increase annual GPP increase R_{eco}, and vice versa. We discover how photosynthesis commences when soil temperature matches mean annual air temperature, scale emergent properties that pertain to how diffuse light affects light use efficiency and the effectiveness of how well vapor pressure deficits may serve as a proxy for soil moisture deficits and down regulate light use efficiency.

To assess fluxes at spatial scales larger than flux footprints, networks of flux data are being ingested into machine learning models and produce maps of carbon fluxes. This degree of upscaling gives the global carbon and hydrological science communities a constraint on global gross primary productivity and evaporation that are based on direct flux measurements. And it is only possible when scientists across the world collaborate and share data.

Viewing ICOS in a global context: from coordinated ocean observations, through high quality data products to global ocean carbon fields and fluxes.

Maciej Telszewski 1, Rik Wanninkhof 2, Benjamin Pfeil, Dorothee Bakker, Christian Rödenbeck,

1 International Ocean Carbon Coordination Project, IO PAN, Sopot, Poland, 2. NOAA-AOML, Miami, FL, USA, 3. ICOS OTC, Bergen, Norway, 4 UEA, Norwich, UK, 5 MPI, Jena, Germany

Over the past two decades systematic automated surface water CO_2 observations are used to map CO_2 levels in the mixed layer over time for robust estimates of air-sea CO_2 fluxes and uptake of CO_2 by the ocean. They contribute two key pieces of information needed to assess the global carbon cycle and impact of fossil fuel release. The first is the fraction of CO_2 released by fossil fuel that is sequestered by the ocean; the second is the trends of surface water CO_2 increase. The fraction of CO_2 absorbed by the ocean is critical for quantifying the ocean's role in modulating the growth of atmospheric CO_2 and the resulting climate change. Trends allow determination of ocean acidification and the oceanic processes that affect, and are affected by, increasing CO_2 levels in the ocean. The observations from the Surface Ocean CO_2 Observing Network (SOCONET) and it's partners address the socio-economic needs of carbon accounting and tracking of the state of ocean ecosystems in support of the UN sustained development goals: *SDGs 13 Climate Action* and *SDG 14 Life Below Water* (www.un.org/sustainabledevelopment/sustainable-development-goals/).

These observations have generated numerous key publications ranging in topics from aquatic chemistry, and process level understanding, to global constraints on the carbon cycle. A tremendous advance took place when data from dozens of research groups were collated and distributed as part of the Surface Ocean Carbon Atlas (SOCAT, https://www.socat.info/), a volunteer community effort initiated by the International Ocean Carbon Coordination Project (IOCCP, http://www.ioccp.org/index.php). SOCAT is a synthesis activity for extensively quality-controlled, surface ocean CO_2 observations by the international marine carbon research community (>100 contributors). SOCAT data is publicly available, discoverable and citable. Since 2011, when SOCAT version 1 was released, the measurements feed directly into the annual Global Carbon Budget updates (Le Quéré et al., 2018), national climate and ecosystems reports (e.g. USGCRP, 2017), and authoritative assessment of the IPCC that are used to set national and international policies (IPCC(AR6), 2018) and the Paris accord (unfccc.int/paris_agreement/).

Currently there are over 23 million data points in SOCAT (version 6), however observations from ships or fixed sensors can only cover a tiny fraction of the spatio-temporal pCO_2 field of the global surface ocean. To obtain continuous air-sea CO_2 flux fields over larger areas or the entire ocean, interpolation methods are needed to estimate values in all the periods and areas not directly observed. This goal was recently achieved via the Surface Ocean pCO_2 Mapping Intercomparison (SOCOM, http://www.bgc-jena.mpg.de/SOCOM/). This community effort benefited from SOCAT data and 14 different mapping methods and investigated similarities and differences in their estimates of regional and global air-sea CO_2 fluxes on a variety of timescales. Resulting analyses led to significant improvements of mapping methods and several high-level publications dealing with global air-sea CO_2 flux and it's reginal and global trends.

In this presentation we will provide an overview of lessons learned from two decades of observations (SOCONET) and a decade of continuous data synthesis effort (SOCAT). We will also share some insights on the use of this data aimed at better quantification of the global carbon cycle (Global Carbon Budget, SOCOM). Scientists involved in ICOS OTC played critical, often leading, role in all these global efforts and this will be highlighted throughout the talk.

Data-constrained annual carbon fluxes for Arctic and Boreal ecosystems

Commane Roisin, Dept. Earth & Env. Sciences, Columbia University, Arllington,, USA

Luke Schiferl, Earth and Environmental Sciences, Harvard University, Cambridge, USA

Carbon-rich permafrost soils of northern high-latitude ecosystems have the capacity to release large amounts of carbon dioxide (CO2) and methane (CH4) to the atmosphere in response to increasing temperatures. Most studies in these ecosystems focus on the growing season, when measurements are relatively easy to make and remote-sensing methods are not light limited. However, understanding the annual budget of carbon gases requires year-round monitoring, during periods when light and weather limit both remote-sensing and airborne measurements. Recent studies have highlighted the importance of non-growing season fluxes to the total annual budget (e.g. 50% of tundra CH4 emissions occur during the non-growing season, Zona et al., PNAS, 2016). Long-term records at Barrow, AK, show that CO2 emission rates from North Slope tundra have increased during the early winter period by 70% ± 4% since 1975, and are linked with rising summer temperatures (Commane et al., PNAS 2017).

Here we bring together data from two NASA airborne programs to assess the regional fluxes of CO2 and CH4 across Alaska between 2012 - 2014 (NASA CARVE) and 2017 (NASA ABoVE). We combine prior models with an atmospheric transport model (WRF-STILT) and airborne data in a geostatistical framework to calculate the spatially and temporally resolved regional flux of CO2 and CH4 across Alaska (CARVE) and Alaska into northern Canada (ABoVE). Our biogenic CO2 flux model (PVPRM-SIF) is driven by remote sensing (including snow cover and solar-induced fluorescence) and meteorological reanalysis products, and is constrained to eddy flux data for ecosystems within the domain. We find that Alaska is, on average, an annual net source of biogenic CO2, but with inter annual variability driven by growing season uptake. We are currently expanding this analysis to encompass northern Canada.

Constraining terrestrial carbon balance through assimilation of remotely sensed biomass data into CARDAMOM

Williams Mathew, GeoSciences, University of Edinburgh, Edinburgh, UK
Anthony Bloom, JPL, Pasadena, USA, Jean-Francois Exbrayat, University of Edinburgh, Edinburgh, UK
Luke Smallman, University of Edinburgh, Edinburgh, UK

Differences among Earth System Model forecasts of the carbon cycle are currently significant, and lead to major uncertainties in predictions of the land sink. These differences have been linked to variations in the internal processing of carbon, particularly in the large pools in biomass and soil organic matter. We show here how new remote sensing products, and novel model-data fusion approaches, advance fundamental knowledge of forest ecology and biogeochemistry, and thereby constrain ESMs. Biomass mapping linked to estimates of net primary production provides a constraint on the turnover time of the biomass pool, a critical model parameter. Using the CARDAMOM model-data fusion system, we show how biomass mapping supports improved parameterisation of carbon cycling for ESMs. We identify regional variations in C turnover currently missing from tropical plant functional types. A sensitivity analysis performed using the CARDAMOM system shows a tropical mean 49% reduction of uncertainty of vegetation C turnover time achieved when assimilating the current state-of-the-art pantropical biomass map. This error reduction has clear spatial variability across latitude and between continents. Further, we use CARDAMOM to show how multiple repeated biomass measurements, for instance from ESA's Biomass Mission, reduce bias on estimates of C increment in aggrading ecosystems, and also on internal process parameters like carbon use efficiency. Finally, we show how CARDAMOM analyses can be used to reliably generate an ensemble average of ESM land sink forecasts.

Recent developments in using isotopic measurements for constraining methane sources and sinks

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Several recent studies have led to different conclusions regarding the utility of measurements of the isotopic composition of methane on diagnosing its budget and trends of sources and sinks. Some studies have found isotopic evidence of a largely microbial source causing the renewed growth in global atmospheric methane since 2007, and underestimated global fossil fuel methane emissions compared to most previous studies. However, other studies have challenged these conclusions by pointing out the substantial range in isotopic source signatures as well as open questions in atmospheric sinks and biomass burning trends. These differing interpretations and conclusions come despite substantial recent scientific contributions to this field including (i) careful comparisons and merging of atmospheric isotope measurement datasets to increase spatial coverage, (ii) in-depth analyses of observed isotopic spatial gradients and seasonal patterns, and (iii) improved datasets of isotopic source signatures. This presentation will provide an overview of the contrasting arguments by distinguishing among the different research objectives including (i) global methane budget source attribution in steady-state, (ii) source attribution of recent global methane trends, and (iii) identifying specific methane sources in individual plumes during field campaigns. We will also present

preliminary results from a current modeling project that will combine and incorporate the most recent available global methane isotopic data (source signatures and atmospheric measurements).

The global carbon balance of forests based on flux towers and forest age data

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Terrestrial gross primary production and energy fluxes have been successfully scaled from ecosystem eddy covariance observations to the global scale. However, this has not been possible for net ecosystem productivity (NEP) because (i) forest age is an important determinant of NEP, (ii) the age distribution of eddy covariance sites is not representative of global forests, (iii) and there was no globally gridded forest age map available. Here we combine maps of forest age with local NEP-age relationships and environmental predictors using machine-learning algorithms to produce new global maps of forest NEP. Globally, forest NEP is a sink of CO2 of 4.9 to 5.3 PgC a-1, mainly in temperate forests and in tropical forests. After removing from NEP the carbon losses that are not observed at flux tower locations, i.e., forest fire emissions, harvested biomass, emissions from leached dissolved organic carbon in rivers, and non-CO2 compounds emissions to the atmosphere such as like volatile organic compounds, the net carbon balance (NBP) estimate of forests is 2.9 PgC a-1 matching well independent forest inventory estimates and atmospheric inversions. This new global estimate of the flux-tower forest carbon balance adds a key piece of information to reduce uncertainties on the still debated location of the global land carbon sink.

Bottom-up and top-down methods in national GHG emission reporting

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Emissions of anthropogenic greenhouse gases are assessed on the basis of national greenhouse inventories. These have to be of high quality and comply with the criteria of transparency, completeness, consistency, comparability, and accuracy. Emission inventories comprise anthropogenic emissions of biogenic and non-biogenic gases which are emitted from five main sectors (energy, industrial processes and product use, agriculture, LULUCF and waste) from a large number of source categories. They are usually calculated by multiplication of ‘activity data’ with representative ‘emission factors’. The more important emissions from a certain source category are, the higher is the demand on data collection and the development of national emission factors and methodologies. Detailed guidance how this has to be done is given by a series of guidelines issued by the IPCC (such as the IPCC, 2006 Guidelines). National emission inventories are annually checked through a review process by the UNFCCC. To ensure GHG inventories of high quality, countries should carry out quality check and quality control procedures and verification. One possible method for verification is the comparison with atmospheric concentrations combined with tools (inverse models) that are able to estimate total GHG emissions from the earth’s surface. Those methods have gone through a rapid development during the last decade(s) and emission fields of CH4 and N2O at national resolution are now available for some countries or regions that have a sufficient density of atmospheric observations. In order to make this approach generally ‘fit’ for providing national GHG emission estimates, further investment in model improvement and atmospheric concentration measurements is required. However, only few

countries currently have the resources and capacity to build system to provide independent national GHG emission estimates based on inverse modelling techniques for into their GHG inventory.

We argue that on the long run atmospheric concentration measurement combined with inverse models have a high potential of providing national GHG emission estimates with uncertainties that for some gases are smaller than those that could be attained with bottom-up methods, as biogenic source categories often are characterized by inherently high variability which makes improvement of its accuracy very expensive. We will develop ideas of a future system of national GHG emission reporting that makes best use of resources and information in order to serve the goals of the Paris agreement.

Connecting global and regional carbon budgets to support policy-making

Ana Bastos

There is an increasing demand for scientific support on climate-related decisions, in particular for providing societies and policy-makers with reliable and up-to-date information about atmospheric GHG. The Global Carbon Project now reports annually on the evolution of CO2 sources and sinks, their uncertainties and the resulting Global Carbon Budget, in phase with the United Nations Framework Convention on Climate Change (UNFCCC) annual Conference of the Parties (COP). Global stocktaking as defined by the Paris Agreement further requires information about regional GHG budgets that should be consistent with the global budgets and regularly updated.

The “REgional Carbon Cycle Assessment and Processes” (RECCAP-1) was promoted by the GCP and carried out by the international carbon cycle research community between 2011 and 2014. RECCAP-1 delivered an unprecedented synthesis of the mean carbon balance and change over the period 1990–2009 for all subcontinents and ocean basins. The global coverage provided, for the first time, opportunities to link regional budgets with the global carbon budget, and to investigate trends in global and regional fluxes. Still, in the latest global carbon budget (LeQuéré et al., 2018, ESSD) top-down and bottom-up estimates show important discrepancies over different latitudinal bands and a non-negligible fraction of the global carbon budget variability remains to be captured by land and ocean models. This underscores the need for regional studies to better constrain key processes/regions in the global C-cycle.

Since RECCAP-1, a wide constellation of satellite-based surface monitoring products and of data-driven products of ocean and land CO2 fluxes became available. This opens the opportunity for novel approaches combining in-situ and space-based observations, inventory data, model simulations and assimilation techniques to produce regularly updated regional land and ocean carbon budgets, consistent with global budgets. This talk will cover recent examples of studies combining multiple approaches to understand regional and global C-cycle anomalies and their drivers, highlighting the potential of engaging the broader research community towards a second “REgional Carbon Cycle Assessment and Processes” (RECCAP-2) supported by the Global Carbon Project.

Combining remote sensing earth observations and in situ networks: detection of extreme events and optimal network size and design

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Remote sensing observations provide important information about vegetation and carbon dynamics on large scales, flux towers in situ measurements at the plot scale. Events important for ecological processes, such as hydrometeorological extremes, often happen at spatiotemporal scales between those covered by these two data sources. We discuss the event detection rates of ecological in situ networks as a function of their size and design. Using extreme reductions of the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), available from satellite missions, as a proxy for substantial losses in Gross Primary Productivity (GPP), we rank historical events according to their severity, and show how many would have been detected with a given number of randomly placed sites, discuss the problem of clustering of sites, and compare the theoretical results with the existing networks FLUXNET and NEON. The further spatio-temporal expansion of the ICOS network should carefully consider the size distribution of extreme events in order to be able to monitor their impacts on the terrestrial biosphere.

Quantification of urban CO_2 emissions in Indianapolis and Auckland

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Cities are often leading the way in CO_2 emission mitigation efforts, both to address the climate challenge and the many associated co-benefits for urban areas. They to understand their emissions both to assess the potential of carbon mitigation strategies and to evaluate the success of such strategies. Commonly, national-level CO_2 reporting is downscaled to provide city-scale emission estimates. Different downscaling methods can produce differences of 50-100% for an individual city, too uncertain to provide meaningful guidance on typical emission reduction targets of 20-30%.

The long-running Indianapolis Flux Experiment (INFLUX) aims to develop and assess methods to constrain urban greenhouse gas emissions that be applied to cities around the world. INFLUX brings together new high-resolution (in both space and time) inventory assessments, a multi-year record of in situ CO_2, CH_4 and CO from tower-based and aircraft-based atmospheric measurements along with a complementary suite of 50 trace gases and isotopes from flasks, and atmospheric modelling. Together, these provide high-accuracy, high-resolution, continuous monitoring of GHG emissions from the city. We compare the bottom-up data product, and top-down tower-based atmospheric inversion and aircraft-based mass balance, in combination with flask observations of radiocarbon in CO_2, to show that urban fossil fuel CO_2 emissions can be constrained to better than 10%, sufficient to allow assessment of proposed emission reduction targets.

We will also present early results from a new study in Auckland, New Zealand, where we work directly with Auckland Council and New Zealand's Ministry for the Environment. We use lessons learned from INFLUX and other studies to tailor the research design and outputs to address the most pressing stakeholder questions and data gaps. This has led to an immediate focus on the partitioning of Auckland's CO_2 fluxes into fossil fuel and land carbon exchange.

Abstracts in Parallel Sessions

Oral Presentations for Session 1: Climate change mitigation – closing the gap between science, inventories and policy making

Conveners: Joanna Post, Lucia Perugini

Climate change mitigation is a challenge that concerns many levels of the society. Even though many processes are political, science is present in various ways. In the highest level, COP decisions within the United Nations framework bind countries to report and reduce their GHG emissions. This system is based on best available science. The national GHG inventories are largely based on emission factors which are defined by scientific publications. On the other hand, recent scientific developments lead to the capability of direct observations of national and global GHG sinks and sources. Concrete example of this policy-science linkage is the zero net emissions objective, Art 4.1 of the Paris Agreement, and the related challenges of how this objective can be achieved and how the net emissions can be correctly captured within the global stocktake process. Solving the socio-scientific challenge of climate change mitigation requires close collaboration. This session focuses on this complex system and shows where the contributions from Earth Observation scientists are most urgently needed.

Updates from the GEO Carbon and Greenhouse Gas Initiative

Heiskanen Jouni, ERIC, ICOS, Helsinki, Finland

Antonio Bombelli, CMCC, Viterbo, Italy, André Obregón, GEO Secretariat, Geneva, Switzerland, Nobuko Saigusa, NIES, Tokyo, Japan, The GEO-C Team, Many institutes, Globe, Switzerland

The budgets of carbon and other greenhouse gases (GHGs) are associated with uncertainties which complicates to evaluate the success of climate change mitigation strategies. Improvements in long-term, high quality observing systems within and across the atmospheric, oceanic, terrestrial and human domains are required to quantify GHG sources and sinks, to understand the climate system, and to assess the level of effort required in order to mitigate and adapt to climate change.

Current carbon observation efforts are a mix of regional and global activities in different, often isolated, contexts. The GEO Carbon and GHG Initiative (GEO-C) in the framework of the Group on Earth Observations (GEO) promotes interoperability and integration across different efforts, particularly at domain interfaces. The aim is a comprehensive carbon and GHG observation and analysis system that provides data for scientists as well as useful and comparable information for resource managers and policy makers.

GEO-C builds on existing initiatives and networks, supports their continuity and coherence, and facilitates actions to fill in the missing pieces for an integrated global system. The initiative addresses policy agendas and operates as a common and open forum to plan and implement strategies and joint activities at the global level from science to policy. Currently GEO-C is working with key organisations such as UNFCCC, IPCC, WMO, GCOS, GCP, Copernicus, ICOS, CEOS, and IG3IS, to take stock of the contributions from all relevant actors, to identify existing gaps and to draft a common roadmap to reach the goals. This presentation will focus on the recent advancements.

Potential of continental CO_2 and $^{14}CO_2$ observational networks to estimate fossil fuel CO_2 emissions via atmospheric inversions

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Combining measurements of atmospheric CO_2 and its radiocarbon ($^{14}CO_2$) fraction and transport modeling in atmospheric inversions offers a way to derive improved estimates of fossil fuel CO_2 ($FFCO_2$) emissions. We developed an isotopic inversion system that can assimilate atmospheric CO_2 and $^{14}CO_2$ data simultaneously. The inversion system is built on the LMDZv4 global transport model at 3.75°×2.5° resolution. We conduct Observing System Simulation Experiments (OSSEs) to investigate the potential of such an isotopic inversion system to estimate the fossil fuel emissions over the Europe and China, in which the uncertainties from the other CO_2 and ^{14}CO2 fluxes are accounted for. By assimilating a massive amount of daily CO_2 measurements and ~1000 2-week integrated $^{14}CO_2$ measurements sampled from continental networks of ~40 sites in one year, the uncertainty in the inverted annual budgets of fossil fuel emissions is below 5% over western Europe and China. Although the results show that by assimilating a large number of daily atmospheric CO_2 data, the inversions can reduce the uncertainties in fossil fuel emissions, the corrections of fossil fuel emissions by using CO_2 data only are not reliable in such an inversion framework. Adding $^{14}CO_2$ data in the inversion and solving for the non-linear relationship between CO_2 and $^{14}CO_2$ fluxes can help largely improve the estimate of fossil fuel emissions. The analyses of the posterior uncertainties in fossil fuel emissions and biospheric fluxes and their correlations indicate that atmospheric $^{14}CO_2$ data can provide valuable information to separate the signals of fossil fuel emissions from those of biospheric fluxes. Given the ability of $^{14}CO_2$ data to separate the different CO_2 flux components, the isotopic inversion method allow for reducing errors in the annual budgets of regional NEE that would arise from a poor representation of the prescribed and fixed fossil fuel emissions in conventional CO_2 inversions.

Assessing the full greenhouse gas balance of EU countries and ecosystems: a first look at different emission estimates and their uncertainties

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European greenhouse gas (GHG) emission reduction policies require accurate and robust estimates of emissions. The management and evaluation of these estimates need to be established and regularly updated using transparent methods, traceable to international standards. New research is required to more accurately quantify carbon stocks and the fluxes of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The development and improvement of methodologies for a GHG verification system will address its applicability in Europe, and, whenever needed, the upscaling from Europe to other GHG emitting countries and regions, through international cooperation mechanisms promoted by the WMO, the IPCC and the UNFCCC in the context of the Paris Agreement on Climate.

Within the frame of the new EU funded project VERIFY aims to develop a framework for the synthesis of different data streams to produce harmonized European country scale GHG national budgets and their uncertainties. By reconciliation of data pertaining to different sources (e.g. bottom-up, top-down, emission inventories and country inventories) we aim to reduce the overall propagation of uncertainty and identify and categorise key differences that are related to specific methods of reporting.

Our preliminary results will be based on reconciled data from UNFCCC-NIR and EDGAR (sector totals) and looking more in detailed at two more uncertain sectoral data: a) agriculture (UNFCCC-NIR, CAPRI, EDGAR and FAO) and b) LULUCF biogenic fluxes - carbon stocks and sinks (UNFCCC, EFISCEN and CBM).

For the sector totals our first investigations show a relatively good match between UNFCCC and EDGAR with differences pertaining mostly to sectoral aggregation in EDGAR and expert judgment emission factors. Large differences are expected for the LULUCF carbon stocks GHG emissions when comparing the modelled results to the UNFCCC NIRs. We hypothesize that differences in method applicability (Tier 1 or Tier 2) might cause as well uncertainties.

Disaggregating the impacts of human activities and natural disturbances on reported greenhouse gas emissions and removals in Canada’s managed forest

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The global land sector is expected to contribute to strategies aimed at mitigating temperature increases through human activities aimed at reducing sources and enhancing sinks, which requires improved quantification of the impacts of human actions on greenhouse gas balances. Current Intergovernmental Panel on Climate Change guidelines for the land sector of national greenhouse gas inventories are based on the assumption that all emissions and removals in managed lands are human caused. However, in Canada natural disturbances in managed forests can result in large and highly variable emissions and subsequent removals which cause large interannual variability and long-term trends in fluxes that can mask the impacts of management activities, including mitigation actions. Building on Canada’s National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) we developed and implemented methods to isolate and quantify the impacts of forest management on trends in anthropogenic emissions and removals in Canada’s managed forest. We partition the total fluxes from land into two components: fluxes from forest lands dominated by natural disturbance impacts and fluxes from the remaining managed forests. The sum of the two flux estimates is equal to net emissions and removals in managed forest lands. Comparing the anthropogenic emissions and removals to those from natural disturbances quantifies their relative contributions to global atmospheric CO_2 concentrations. Disaggregating highly variable natural disturbance fluxes from the remaining fluxes in managed forest lands increases the understanding of how human activities impact flux trends and increases the ability to quantify and document if forest sector mitigation actions have contributed to reduction in sources and increases in sinks. Moreover, this disaggregation of fluxes increases the ability to quantify trends in emissions and subsequent removals associated with natural disturbances.

Assessing GHG exchange at landscape scale: quantifying field-scale fluxes using low-cost methods as well as regional scale fluxes using flux aircraft

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West-European landscapes are often a mixture of agriculture, pastures, woodland and nature. While the need to enlist every piece of land to help sequester, or at least avoid emissions of, greenhouse gases, this naturally conflicts with other use objectives of the land. Solutions could be sought in clever, compensating, measures and spatial planning of the landscape. For peat meadow soils, measures that promote elevated groundwater levels are being tested in practice while in other land use types, pilots are being planned. This calls for methods to quantify GHG exchange of small patches as well as a sound quantification of typical GHG exchange by land-use type. Within the scope of several projects (ERA-GAS (GHG-Manage & PEATWISE) and ' NL-Smart Land use') we are designing methods for just that. We will explore the feasibility to measure Eddy-Correlation, variance-based, budget- and surface-renewal methods for small patches, serving to verify the effectivity of dedicated measures intended to protect and enhance soil C accumulation. At the same time, we explore the practical usefulness of airborne flux data to map and classify GHG exchange for the main land-use and soil types of both the Netherlands and North-Eastern Germany.

Posters for Session 1: Climate change mitigation – closing the gap between science, inventories and policy making

ICOS works towards harmonised and societally relevant data and services

Heiskanen Jouni, ERIC, ICOS, Helsinki, Finland

Eija Juurola, ICOS, Helsinki, Finland, Janne-Markus Rintala, ICOS, Helsinki, Finland, Evi-Carita Riikonen, ICOS, Helsinki, Finland, Emmanuel Salmon, ICOS, Helsinki, Finland, Alex Vermeulen, ICOS, Lund, Sweden, Ari Asmi, ICOS, Helsinki, Finland, Werner Kutsch, ICOS, Helsinki, Finland, the ICOS RI Team, ICOS, Europe, Finland

ICOS was built on the work done by many research groups in various projects, and currently ICOS is the European pillar of carbon (C) and greenhouse gas (GHG) observations. As a data and elaborated data products providing Research Infrastructure, ICOS has special role and responsibility to serve wide user communities, from scientists to end-users utilising GHG related information in their work. In practice, this means interdisciplinary and cross-societal-sector cooperation because the fundamental cycles of C and GHGs are important for all ecosystems and in the core of climate change.

Environmental research relies on data provided by environmental Research Infrastructures, which are in Europe coordinating actions through the ENVRI community. Within this community ICOS is strongly promoting actions towards harmonised data flows between data providers. Cross-region cooperation is also vital, and ICOS contributes specifically into the development of African environmental observations (project SEACRIFOG).

Societal needs for climate-related data have become more and more evident. Climate change mitigation and adaptation influences many levels of societies which calls for targeted actions and more coherent overall coordination. ICOS is a key data provider and contributor in the VERIFY project that focuses on improving national emission inventories. In the highest political level, ICOS participates in the work of UNFCCC and its Subsidiary Body for Scientific and Technological Advice, SBSTA. ICOS hosts the secretariat of GEO Carbon and Greenhouse Gas Initiative (GEO-C) which is a joint effort between many organisations towards policy-relevant global carbon cycle observation and analysis.

This presentation focuses on identified key issues where more work is needed to make this complex system to operate more harmoniously together.

Restoring a tired pasture: what impact on greenhouse gases exchanges?

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The restoration of permanent pastures is often required in order to restore a productive state and the palatability of the grass. The restoration process consists on destroying the former vegetation using herbicides followed by tillage and reseed. The short term and long-term impacts of such operations on the carbon cycle and N2O emissions are not well defined for old permanent pastures.

Therefore, a paired flux tower measurement campaign was started in March 2018 at the Dorinne ICOS candidate station in Southern Belgium, with the aim to study the impact of pasture restoration on CO2 and N2O exchanged by the ecosystem. The site is a 100-years-old intensively managed grassland which last restoration was performed more than 40 years ago. It is grazed by Belgian blue beef cattle and fertilized with around 120 kgN ha-1 per year on average, reflecting common practices in the area. A former study carried out at the same site, showed that the pasture acted as significant carbon sink before the start of experiment.

Two adjacent parcels belonging to the same farm were both equipped with identical instrumentation including eddy covariance measurements of CO2 (LICOR 7000) and N2O/CH4 (Aerodyne Inc. quantum cascade laser) exchanges to allow the comparison between a control and a restored plot subject to identical pedo-climatic conditions. Preliminary results of greenhouse gas fluxes will be presented in relation to climatic conditions and management operations and the evolution of soil ammonium and nitrate.

Findings from SEACRIFOG Stakeholders Consultation Workshops

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The SEACRIFOG project promotes the EU-Africa cooperation dialogue at different levels (policy, science, society) on the following themes: land use, land use change, climate-smart agriculture, food security, carbon cycle and greenhouse gases (GHG) observations, in order to support climate adaptation and mitigation. The project shall develop a road map towards an African network of research infrastructures (RI) for long-term observation of GHGs, climate change and environmental dynamics. In order to engage relevant stakeholders from Africa and EU, we organized 3 consultation workshops. 73 participants from 33 organizations attended the three stakeholders workshops (held in Kenya in May 2017, Ghana in June 2017, and Zambia in April 2018) in order to share their knowledge about: 1) Land use change implications on food security, 2) GHG observations, carbon stocks and climate change mitigation, 3) Climate smart agriculture in Africa. The most prominent and common issues raised, were about data and metadata availability, accessibility, usability, interoperability, resolution. Capacity development particularly training programmes are needed for GHG monitoring, ArcGIS. The importance of sharing data and knowledge and the need to develop not only technologies and research infrastructures but also strong and collaborative networking was emphasized. Decision-makers at various levels need an improved access to current know-how and capabilities on new technologies and best practices. Beside scientific and technical aspects, the solution to part of constraints must be a comprehensive approach considering also socio-economic dynamics which may influence the success and the long-term sustainability of RI network Science alone is not enough, thus mediation among scientists and stakeholders along the entire chain of end users could help in facing some of the crucial aspects. A coherent and thorough analysis and prioritization of all these issues will help in developing a basket of options suitable for specific "on field" conditions, at national or regional level.

The devil in reducing emissions in the long-term: The underestimated “now” versus the overestimated “then"

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Piotr Zebrowski, Advanced Systems Analysis Program, Internatl Institute for Applied Systems Analysis, Laxenburg, Austria

This presentation is a perspective piece, on research still to be conducted. We aim to elaborate on the usefulness of greenhouse gas (GHG) emission inventories in reconciling short- and long-term emission estimates. Given that emission paths are sensitive to historical conditions, as well as uncertain with respect to their mandated reduction levels, experts are grappling with the probability that long-term targets will be missed.

Here we ask whether we can deal with the issue of path dependency from a data-processing perspective by way of advanced data integration. To this end, we pose two conditions. First, we restrict ourselves to systems with memory. Memory allows to reference how strongly a system’s past can influence its near-term future. Second, we make only a “small” step into the future.

The notion of memory suggests approaches that characterize its impact on both the dynamics (trend) of a system and the fluctuations around that trend. The challenge is to separate the two while treating memory consistently.

Different approaches are able to capture memory. We capture memory with the help of three characteristics (temporal extent, weight and quality over time). How well do we need to know these characteristics in order to delineate a system’s near-term future, which we seek to do by means of the system’s explainable outreach

[EO]? We argue that we have reasons for optimism that the system's EO can be derived under both incomplete knowledge of memory and imperfect understanding of how the system is forced.

Our insights indicate the high chance of our conjecture proving true: being ignorant of memory, we underestimate the persistence with which GHG emissions will continue on their historical path beyond today and thus overestimate the amount of reductions that we might achieve in the future. We argue that quantifying memory and persistence should become standard.

Bioenergy with carbon capture and storage at regional scales: interactions with the food-energy-water nexus, regional climate, and biodiversity conservation

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Carbon dioxide must be removed from the atmosphere to limit climate change to 2 °C or less. The integrated assessment models used to develop climate policy acknowledge the need to implement net negative carbon emission strategies, including bioenergy with carbon capture and storage (BECCS), to meet global climate imperatives. The implications of BECCS for the food, water, energy, biodiversity, and social systems (FWEBS) nexus at regional scales, however, remain unclear. Here, we present an interdisciplinary research framework to examine the trade-offs as well as the opportunities among BECCS scenarios and FWEBS on regional scales using the Upper Missouri River Basin (UMRB) as a case study. We describe the physical, biological, and social attributes of the UMRB and outline a "conservation" BECCS strategy that incorporates societal values and emphasizes biodiversity conservation. We also demonstrate how land management trends to date have favored convective precipitation during the early growing season while improving soil C conservation and farm-scale economic returns. Despite this "triple-win" for regional climate, conservation, and the economy, the study area is still prone to drought, and the "flash" drought of 2017 was in some places the worst in recorded history. We demonstrate that convective precipitation was anomalously unlikely before the drought and discuss how drought forecasting may be improved by incorporating convective likelihood. As a consequence, any regional C sequestration strategy should incorporate regional climate analyses.

Implications of carbon emissions from Chinese cities

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China's urban population grew up to 670 million in 2010, nearly 50% of the total population. Another 210 million formerly rural residents are expected to migrate into China's cities by 2020, equivalent to create one megacity like Beijing or Mexico every year from 2010 to 2020. As urban residents consume nearly three times the energy than their rural counterparts on average, such high speed of urbanization will bring huge pressures on China's CO2 mitigation target. In this study, we quantify the carbon emissions for 50 Chinese cities during 2000-2014, and analyze the physical and economic characteristics that underlie the carbon emissions. In the previous works, we have developed carbon emission inventories for some Chinese cities using a consistent methodology, which is adapted of the IPCC production-based approach for nations, but include the prominent trans-boundary emissions relating electricity and heat consumptions of cities. We grouped the sources of CO_2 emissions from Chinese cities into industry (energy use and process), transportation and buildings. We find the per capita emissions of Chinese cities have great diversity from 2.5 to 25 tons in 2010, which refers to the substantial disparities in terms of natural (e.g. geographical location, climate, and resource and energy endowments) and socioeconomic status (e.g. economic development and structure, population density and lifestyles) among Chinese cities. For an individual city, the per capita emissions are significantly related to per capita GDP with a positive and inverted U shape, which is committed to the traditional shape of environmental Kuznets curve. The per capita emissions of most cities reach the summits and start to go down when their per capita GDPs reached the level around 21,000 USD (2011 PPP). The policy implications for stabilizing and mitigating the emissions of Chinese cities have also been discussed to meet the goal of the Paris Agreement.

Oral Presentations for Session 2: From data to useful services with societal meaning

Conveners: Mikko Strahlendorff, Jean-Noël Thépaut

Climate change services have not yet found wide application. Reports for governing bodies is the norm then a much more data intensive and targeted service can be envisioned. For example, investments in real estate could benefit from climate predictions greatly. Maybe an individual prediction product needs to be produced for private interests to understand the values. Public services on the other hand are becoming more data driven and targeted.

Urban Onroad CO_2 emissions and population density: tipping points and saturation effects

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Onroad fossil fuel CO_2 (FFCO2) emissions account for ~30% of FFCO2 emitted in the U.S and 60% of total onroad US FFCO2 emissions occur in urban areas. Increasing urban population density has been considered an effective approach to lowering onroad FFCO2 emissions. However, the relationship between urban population density and per capita onroad FFCO2 emissions remains poorly quantified and understood. To what extent, and at what densities, would increases in population density lead to lower per capita onroad FFCO2 emissions? Is this relationship regionally-specific or specific to different urban configurations? To answer these questions, we analyze a new high-resolution (1 km^2) onroad FFCO2 emissions data product (Vulcan v3.0) at the block group scale and find that a 10% increase in population density is accompanied by a decrease in onroad per capita FFCO2 emissions by as much as -8.5% in the urban core and -6.2% in the suburbs. All US regions show a diminishing return to population density as levels approach 3,000 ppl/km^2, after which the relationship saturates. Suburban areas, by contrast, show increasing returns to rising population density levels in the US West and South across all density levels but a weakening of the relationship in the Northeast and Midwest beyond 1,000 ppl/km^2 and 1,500 ppl/km^2, respectively. To assess the accuracy of the onroad emissions used in this study, we compare the Vulcan v3.0 onroad FFCO2 emissions to the DARTE onroad FFCO2 emissions, comparing both to a collection of observationally-based point estimates of onroad traffic. We find greater consistency between Vulcan v3.0 and the observationally-based onroad FFCO2 in comparison to DARTE.

Anomalous sea-air CO2 flux in the North Tropical Atlantic during 2010 evidenced by modelling and observations

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The continuous monitoring of the fugacity of CO2 (fCO2) using merchant ships enable us to better understand the link between CO2 and climate variability. In the tropical North Atlantic (TNA) (0 - 30° N, 70° W - 15° W), higher than usual fCO2 are associated with positive sea surface temperature (SST) anomalies, particularly pronounced in boreal spring 2010. The warm anomalies are attributed to climatic events (Pacific ENSO in 2009, strong positive Atlantic Multidecadal Oscillation) that affected the sea-air CO2 flux in 2010.

The observations from two merchant ships are generally in accordance with the Mercator SST outputs, sea surface salinity (SSS) and surface fCO2. The anomalous warming of 2010 is also well reproduced by the model. The Mercator model is thus used to evaluate the causes and extension of this event and its impact over the sea-air CO2 exchange in the region.

Over the 2006 - 2014 period, strong positive fCO2 anomalies occur in boreal spring 2010 when the SST anomalies are the strongest. Mercator results show that SST anomalies are the main drivers of fCO2 anomalies in the western tropical Atlantic in 2010. At the same period, near the African coast, positive SST anomalies associated with negative inorganic carbon anomalies are caused by a weakening of the coastal upwelling. Although they appear mostly in spring, the fCO2 anomalies of 2010 affect the annual CO2 budget and lead to an increased CO2 outgassing twice as large (40.7 Tg C year-1) as the mean over the 2006 - 2014 period (20.5 Tg C year-1).

Floodplain forest greenhouse gas fluxes in changing climate

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Floodplain forests play an important role in terms of the global carbon, nutrient and hydrological cycling, sediment deposition and the maintenance of species biodiversity. They are very dynamic systems representing an interface between terrestrial and aquatic ecosystems. Their functioning strongly depends on the presence or absence of water. Recent changes in floodplain forests in central Europe are mainly caused by hydrological management as well as more frequently occurring droughts in the course of climate change.

The ecosystem station Lanžhot (ICOS CZ-Lnz, proposed as a class 1) is located in a floodplain forest, 6.5 km north of the confluence of Morava and Dyje rivers in Czech Republic (48° 40.090 N, 16° 56.780 E). The long-term average annual precipitation at this site is around 550 mm and the mean annual temperature is 9.3 °C. The average groundwater level is -2.7 m. Since a long time flooding occurs here very rarely, the last flooding event was in 2013. In addition, the site is managed hydrologically. Consequently, the water regime of the site changed over the years and represents nowadays relatively dry conditions for such type of ecosystem.

Our main research goal at Lanžhot is the evaluation of floodplain forest greenhouse gas exchange in future climate based on its current CO2, H2O and CH4 fluxes and based on historical information about water stress impacts on tree growth and carbon capture. The recent fluxes will be derived via the eddy covariance and chamber methods, historical information from before and after the start of hydrological management via dendrochronological methods. Consequently, we have at Lanžhot the unique possibility to answer questions on how floodplain forests may generally behave in the course of climate change with constantly drier conditions.

Model for climate services development

Mikko Strahlendorff, Finnish Meteorological Institute

Currently climate services that support public or private sector decision making are still predominantly reports like more targeted IPCC assessment reports that combine the complex and huge data sets involved into statements from climate experts. This does imply a more general result that surely leaves potential untapped in the very large data sets involved.

In weather services there is a certain process for investigating time series information (for example retail sales data) from a potential user. The task is to transform observation or forecast data into comparable time series and making correlations between the two. High correlations between weather parameters and user data reveal the potential services. The Finnish Meteorological Institutes commercial weather arm is serving these for sparkling water and sausage sales or similar weather-related activities. In Austria the https://www.wedda.at/ service is making similar weather driven demand analysis.

This is a basic model to follow for climate services and especially seasonal forecasts development. Expanding the data involved from physical atmosphere variables towards atmospheric composition parameters as well should open even more application areas. A particularly interesting area are CO2 emission related services where for example a city would track their emission forecast based on heating needs and the natural CO2 sinks to be able to perform climate neutral operations.

Towards an anthropogenic CO2 emissions monitoring system

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In the wake of the agreement signed in Paris at the UNFCCC's 21st Conference of the Parties (COP-21) in December 2015, the need to monitor and to inform about the effectiveness of mitigation efforts for anthropogenic emissions of key greenhouse gases has become more acute and prominent. With its global coverage (or regional in the case of geostationary platforms), Earth Observation has a decisive role to play within such a monitoring system, complementing ground-based observations, "bottom-up" estimates of the emissions (included in official reporting) and atmospheric transport modelling.

In the context of Copernicus, the European Commission commissioned a report from a group of experts about the opportunity and the feasibility of an Earth Observation mission that could target anthropogenic emissions of CO_2. This report has been published in October 2015 and proposes an "implementation strategy for a European initiative that includes a space-borne observation capacity contributing to a system with full operational capabilities at the horizon 2030 and beyond". The overarching objective is "to enable the accurate, transparent and consistent quantification of fossil CO_2 emissions and their trends at the scale of megacities, important industrial sites, small regions, countries, and the Earth as a whole. Such a capacity would provide the European Union with a unique and independent source of actionable information, which would address multiple stages of the policy cycle. Furthermore, this capacity will contribute to a system at global level through integration with similar efforts from third parties."The emerging of reliable and policy-relevant services and products is confirmed to be a major technical and scientific challenge, requiring extensive research efforts in order to improve on the current state-of-the-art.

This presentation will review research efforts initiated by the European Commission that are already underway on progressing with the specification and development of such a future monitoring system. The CHE (CO_2 Human Emissions) project, coordinated by ECMWF, aims specifically at assembling the relevant community in Europe to prepare for a future monitoring system of CO_2 emissions and focuses on investigating the model and data assimilation system components as well as theoretical aspects and the delivery of so-called "Nature Runs" of CO_2 (at the global scale using IFS and over selected local areas with very fine spatial resolution using limited-area models), which will be pivotal for observing network and instrument design studies. The VERIFY project , led by CEA (France) is more research-oriented and has a wider focus than just anthropogenic CO_2 emissions by investigating similar principles for CH_4 and N_2O as well as looking at the effects of land-use change, for example.

Last but not least, we will describe how ECMWF ambitions to play a major role in a possible future Copernicus anthropogenic CO_2 emissions service, based on its existing infrastructure, operational know-how, and accumulated relevant expertise within the Copernicus Atmosphere Monitoring (CAMS) and Climate Change (C3S) Services.

http://www.copernicus.eu/main/towards-european-operational-observing-system-monitor-fossil-co2-emissions

Posters for Session 2: From data to useful services with societal meaning

ICOS ATC Metrology Lab: Evaluating different GHG sampling systems for background atmosphere monitoring station.

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Carole Philippon, LSCE, Gif-sur-Yvette, France, Rodrigo Rivera, LSCE, Gif-sur-Yvette, France, Camille Yver Kwok, LSCE, Gif-sur-Yvette, France, Leonard Rivier, LSCE, Gif-sur-Yvette, France, Michel Ramonet, LSCE, Gif-sur-Yvette, France

In the framework of the European research infrastructure ICOS, aiming to provide harmonized high precision data for advanced research on carbon cycle and greenhouse gas (GHG) budgets over Europe, the Atmosphere Thematic Centre (ATC), located at LSCE in France, hosts the Metrology Lab, a facility mainly dedicated to elaborating measurement protocols and evaluating performance of GHG analyzers. In addition to the assessment of the ICOS compliance of the analyzers before deployment in the ICOS monitoring station network, the Metrology Lab assesses the suitability and the performance of different sampling systems such as dryer or controlled buffering sampling unit which suppose to improve the representativeness of discrete data (e.g. while a single analyzer measure at several heights on a tall tower).

The presentation will give an overview of the results of the tests conducted at the ATC Metrology Lab and will focus on the performance of air dryer and air buffering system.

Regional Carbon Budget of Saxony (Germany) Based on Flux Measurements and Inventories

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The net carbon sink of managed ecosystems (forests, agriculture) can be determined using repeated inventories of carbon pools (biomass, soil) in regular grids and using long-term continuous Eddy Covariance flux measurements at, e.g., ICOS sites. In Germany, inventories (National Forest Inventory, National Forest Soil Inventory, Soil Monitoring) exhibit a good spatial representativeness but also the typical low temporal resolution. ICOS measurements offer the opportunity to study abiotic and biotic drivers of GHG fluxes and can address different land uses and management effects in the carbon budget.

A combination of both approaches combines the mutual advantages regarding the need of regional carbon budgets. It allows to study intra- and interannual variability and to arrive at emission factors depending on land use, management and disturbances at ICOS sites.

As examples, the long-term net CO_2 sink (NEP) of an old spruce forest at the Anchor Station Tharandt (ICOS class 1 site, labelling in progress) is 17 tCO_2 ha^{-1} a^{-1}, whereas the NEP of the agricultural site Klingenberg (5-year crop rotation, associated ICOS site, labelling in progress) is 3 tCO_2 ha^{-1} a^{-1} only. Including lateral C fluxes (thinning, harvest, organic fertilisation) the respective NBP numbers are 9 tCO_2 ha^{-1} a^{-1} (forest) and -5 tCO_2 ha^{-1} a^{-1} (crop), respectively.

Saxony is a German country with considerable electricity production from brown coal. Therefore, the regional carbon budget of Saxony (Germany) includes large CO_2 sources of 48 Mt CO_2 a^{-1} (2012) mainly due to these combustion plants and traffic. CO_2 sinks of forest ecosystems are estimated to amount to 6 Mt CO_2 a^{-1} (2002 – 2012). So, around one eighth of the Saxonian CO_2 emissions are absorbed by the Saxonian forests. The contribution to climate change mitigation is primarily due to the replacement of fossil resources, while compensating emissions is an accompanying effect.

Substomatal conductance of Scots pine is driven by vapour pressure deficit: leaf chamber measurements of COS fluxes

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Carbonyl sulfide (COS) is an important tracer of stomatal conductance of plants due to its shared metabolic path with carbon dioxide (CO_2). Unlike CO_2, COS is fully hydrated in plant's leaves by carbonic anhydrase, so there are no respiration-like emissions from the plant. Plant leaf conductance could be separated into stomatal conductance (controlling plant's uptake of CO_2 and losses of water), mesophyll conductance (reflecting a conductance to CO_2 diffusion in mesophyll) and biochemical conductance (reflecting a biochemical photosynthetic capacity). Studying all these processes is important to understand what limits a plant photosynthetic activity under various conditions, especially as more frequent extreme weather situations are expected under on-going climate changes. However, unlike stomatal conductance, substomatal (mesophyll and biochemical) conductance is still understudied.

We measured COS emissions from a Scots pine at Hyytiälä ecosystem research station, Finland, during a spring and summer in 2017 with transparent branch chambers, together with ancillary CO_2 exchange and meteorological measurements. Based on the CO_2 daytime fluxes, we obtained overall leaf conductance, which could be separated into stomatal (from COS exchange) and substomatal conductance. Meteorological drivers of substomatal conductance were then studied. Using multivariate regression methods and path analysis, we observed a strong significant direct effect of vapour pressure deficit (VPD) on substomatal conductance, which cannot be fully explained by any indirect effects of VPD on other factors possibly driving substomatal conductance, i.e. air temperature, relative air humidity, water potential or stomatal conductance.

Seasonal and diurnal variability in temperature dependence of stem CO_2 efflux from Norway spruce trees

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The exponential temperature function of CO_2 efflux has been generally applied in a numerous models. However, the relationship can be affected by other environmental and physiological conditions (e.g. drought, photosynthesis rate, growth). Neglecting this variability can lead to high inaccuracy of the models.

In this study, we investigated seasonal variability of parameter Q_{10} (characterising CO_2 efflux response to temperature) and also an effect of a period of a day when measurements are taken on this parameter. For the analyses, we used continuous measurements of stem CO_2 efflux from the stem surface and stem temperature on eight trees from May till October of seven years.

Seasons were divided into seven periods on the basis of stem growth rate. Q_{10} ranged between 1.61 and 3.46 and varied over the season with the lowest values occurring in July and August when stem growth processes are expected to be the most energy demanding. On the contrary, the highest Q_{10} was observed in October which was considered as a post-growing period. Q_{10} calculated from whole-season data set (May – October) significantly overestimated Q_{10} .

Days (24 hours) were divided into four periods on the basis of transpiration stream rate. Q_{10} calculated for four periods of day was higher compared to Q_{10} calculated from 24-hour data except for the early afternoon. The Highest Q_{10} was observed in night time with zero transpiration stream, while the lowest in early afternoon with when the transpiration stream reached the highest rates.

Oral Presentations for Session 3: Major research questions in Earth Observations

Conveners: Pavel Kindlmann, Beryl Morris

Currently many major global changes occur at the same time. Many of these are interlinked and understanding the complex interactions highly benefit from integrated approach across scientific fields. Increasing CO2 levels and warming climate cause migration of vegetation and changes in growth rates, which can be seen by remote sensing as 'greening of the planet'. Also plant diseases and parasites, and herbivores, spread with environmental changes and threat e.g. food security. These changes may be more feasibly detected in terrestrial ecosystems compared to e.g. Arctic Ocean, where less parameters, such as ice extent, can be detected using satellite observations. However, it seems that not only the Arctic Ocean is warming, but that its carbonate system changes resulting in ocean acidification. All of these changes increase the uncertainty of future projections of GHG cycles. This session specifically welcomes topics that are related to carbon and GHG cycles and have use of these data.

Performing a partial harvest instead of clearcutting causes less greenhouse gas emissions in a peatland forest

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Peatland forests in Finland are widely reaching harvesting age and the method used for the harvesting may have a significant impact on the greenhouse gas (GHG) balances. Nowadays, the most common method of forest management in Finland is rotation forestry including clearcutting and forest regeneration, but clearcutting is known to increase methane (CH_4) emissions and greatly change the soil hydrology. Our aim was to study to what extent the adverse environmental impacts of peatland forestry could be reduced by making a partial harvest instead of clear-cut.

The experiment was conducted at a nutrient-rich peatland forest (Lettosuo, Tammela in southern Finland). At the partially harvested plot in the forest, ca. 75% of the tree biomass was removed in spring 2016. In addition, we retained an uncut control and set up a clear-cut plot at the site to compare the impacts of different management practices on site conditions. The effect of harvests on water table level (WTL) and GHG fluxes and evapotranspiration were studied using the data collected with the eddy covariance method before (2009–2015) and after (2016–) the partial and full harvests. In addition, manual and automatic chambers were used to measure GHG exchange at the forest floor before and after the harvest.

The results show that the WTL at the partial harvest rose less than at the clear-cut as compared to the control plot. The harvested plots turned from carbon dioxide (CO_2) neutral into a CO_2 source, but the emissions from the partial harvest were only 25% of those from the clear-cut. A 25% decrease in CH_4 sink was found after the partial harvest whereas clear-cut turned into a small CH_4 source. Nitrous oxide (N_2O) fluxes were both spatially and temporally highly variable, but a significant increase in emissions was observed at both harvested plots.

The greenhouse gas balance of a managed boreal forested landscape measured from a tall tower in northern Sweden

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Climate change is mainly driven by the rising greenhouse gas (GHG) concentrations in the atmosphere, with carbon dioxide (CO_2) and methane (CH_4) accounting for ~80% of the total radiative forcing from well-mixed GHGs. Boreal forested landscapes exchange large amounts of CO_2 with the atmosphere via photosynthesis and respiration and are considered important carbon sinks for mitigating climate change. Emissions of CH_4 are generated from the boreal mires and the living biomass, plant litter, and woody debris under anaerobic conditions in the forests; meanwhile, CH_4 is consumed by the well-aerated soils. Due to landscape heterogeneity, it is currently under debate whether the managed boreal landscape is a sink or source of GHGs. In addition, technical challenges for quantifying GHG budgets at a landscape scale introduce large uncertainties. In this study, we provide the first baseline estimates of CO_2 and CH_4 fluxes over a managed boreal landscape (~68 km^2) in northern Sweden, using a tall eddy covariance (EC) flux tower. From March 1, 2016 to February 28, 2018, the boreal landscape was a net sink for atmospheric CO_2, with a mean annual NEE of -87 g C-CO_2 m^{-2} yr^{-1}. The mean CH_4 flux was 3.3 mg C-CH_4 m^{-2} d^{-1} from July 13 to October 31, 2017 and the estimated annual CH_4 flux was 0.8 g C-CH_4 m^{-2} yr^{-1}. Given the global warming potential of CH_4 (28) over a 100-year time horizon, the overall GHG budget of the boreal landscape was approximately -2.9 t CO_2-eq ha^{-1} yr^{-1} and indicated the landscape to be a sink for radiative forcing. Challenges (e.g. storage and advection corrections, tower location bias, landscape heterogeneity effects) and opportunities associated with tall tower measurements are also discussed in this study.

Decomposition of the climate change scenario uncertainty effect on primary production of boreal forests

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Uncertainties of the development of forest productivity in a changing environment are still large even in countries of long forest management history like Finland. Two fluxes, Gross Primary Production (GPP) and heterotrophic respiration, determine in a large scale forest productivity. Here we use simple ecosystem model, PRELES, for analyzing the role of input, structural and parametric uncertainty on GPP of Finnish boreal forest. The CMIP5 and CMIP3 model ensembles in RCP and SRES scenario families formed the analyzed input uncertainty while the structural uncertainty of PRELES was analyzed through the relationships between atmospheric CO2 concentrations (Ca), photosynthesis and water use of trees. The parametric uncertainty of PRELES was determined from the parameter posteriori distribution created with Bayesian statistics.

According to our results, the scale of productivity change largely depends on the long-term Ca fertilization effect on GPP and transpiration. However, variability between Global Circulation models (GCM) was the main source of uncertainty, from 90% at the beginning of the simulation period to ca. 50% until 2060. During latter part of the century emission scenario/pathway became the dominant factor. The highest predictions of GPP were almost double compared with present day observations, while the lowest predictions without Ca fertilization effect did not increase GPP during the next decades and barely during the whole century. The species specific mean GPP increased in all simulated cases and was generally in the same scale as found in earlier studies with more mechanistic models. Our finding that the decomposition of uncertainty hardly

differed between combinations of older SRES emission scenarios and CMIP3 projections and the currently used RCPs and CMIP5 GCMs lends support to the robustness of this result. Large uncertainties may hinder the implementation of mitigation strategies, yet a thorough assessment of uncertainties is important to draw robust conclusions.

BONUS INTEGRAL: Using ICOS and related infrastructure to improve biogeochemical monitoring and ecosystem assessment for the Baltic Sea

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ICOS, as one of the large-scale European infrastructures, is funded nationally, and organized along its three thematic branches: atmosphere, ecosystem, and ocean. Its main purpose is to provide a network of greenhouse gas concentration and flux measurements at the highest quality level. Yet, regional clustering, and incorporation of similar infrastructure not part of ICOS, bears an enormous potential to foster biogeochemical understanding of ecosystems, and to improve or augment environmental other large-scale monitoring efforts.

The project BONUS INTEGRAL, funded jointly by the European Commission and the contributing pan-Baltic national funding agencies, seeks to demonstrate and exploit the potential added value of ICOS for the ecosystem state monitoring of the Baltic Sea as an important contribution to an improved HELCOM monitoring. In direct response to the requirements of the European Marine Strategy Framework Directive, BONUS INTEGRAL will provide new approaches for the monitoring of marine eutrophication and acidification through assessment of the carbon system, and explore the integrated greenhouse gas flux as a potential new ecosystem health indicator.

The ocean component of ICOS in the Baltic comprises the flux tower Östergarnsholm, the combined ocean/atmosphere station Utö, and the VOS line Finnmaid commuting between Helsinki and Lübeck. In particular the latter, operated already since 15 years, has been used for a wealth of studies addressing primary productivity, nutrient stoichiometry, and nitrogen fixation in the Baltic Sea. Within BONUS INTEGRAL, amendments and new installations are in progress, including a new pCO2 line close to the mouth of the River Vistula, and autonomous carbon system and greenhouse gas measurements on VOS Transpaper, traversing the Gulf of Bothnia.

The talk will provide an overview of the project, its rationale, and give examples of the thrilling science behind it. It also advocates for a strong “ocean” component in the Baltic Sea area.

Quantification of different uncertainty sources on modelled climate change indicators in future climate scenario estimates

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We present the results of quantifying the model, climate driver and representative concentration pathway (RCP) uncertainties for two impact/ecosystem models on two coniferous forest sites in Finland. The model uncertainty for both models was represented by a set of 100 parameter values drawn from the parameter probability distribution; the climate and RCP uncertainties followed from nine different sets of climate drivers under two RCP scenarios (4.5 and 8.5).

The models were run with all of the above combinations for a period of 120 years (1980-2100), accumulating in 900 simulations per model. We examined indicators of the impact of climate change on boreal ecosystems, that included net ecosystem exchange, gross primary production, evapotranspiration, length of vegetative active period, soil respiration, albedo and the number of snow days. The source of variance in each indicator was attributed to changes in the uncertainty components.

We present the highlights of the analysis from the different indicators as well as their uncertainty sources and a synthesis of all the results.

Posters for Session 3:
Major research questions in Earth Observations

Estimating carbon gas exchange with inland waters of the USA

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David Butman, School of Environmental and Forest Sciences, University of Washington, Seattle Washington, USA, Zhiliang Zhu, Land Resources Mission Area, U.S. Geological Survey, Reston Virginia, USA

Streams, rivers, lakes and reservoirs contribute to the carbon cycle by transporting, storing and biogeochemically reacting terrestrial and aquatic carbon in amounts that are quantitatively important at local to regional and national scales. Biogeochemical processing of carbon by these inland waters results in flux of carbon dioxide and methane across the water – air interface, commonly at rates that far exceed rates occurring on land. These fluxes are driven by concentration gradients and gas transfer velocities that are highly variable within and among water bodies and seasonally. Moreover, some of the largest rates of gas exchange occur with small streams and lakes that are poorly characterized spatially and temporally across landscapes. This creates challenges requiring extensive and intensive data acquisition across scales, coupled with the need for models that accurately calculate gas emission and/or uptake using commonly determined environmental conditions. Exchange of carbon dioxide is largely driven by local geochemical and climatic conditions and biological processing. Methane is continuously emitted by essentially all open-water bodies at highly variable rates that are determined by in situ production, organic carbon availability, and water body size and type. We present results and progress on efforts by the U.S. Geological Survey and collaborators to quantify emissions of these carbon gases from the inland waters of the USA.

Neural network estimation of CO_2 partial pressure in surface seawater of the Mediterranean Sea

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Catherine GOYET, UPVD, IMAGES ESPACE-DEV, Perpignan, France, Franck TOURATIER, UPVD, IMAGES ESPACE-DEV, Perpignan, France

The distribution of partial pressure of carbon dioxide (pCO_2) in surface seawater is particularly important today in the context of global change, since it is used to evaluate the concentration of anthropogenic carbon that penetrates into the ocean. Unfortunately, few pCO_2 data are available, and, contrary to other seawater characteristics, they cannot be directly measured by remote sensing. In the Mediterranean Sea, we estimated these partial pressures from temperature (T), salinity (S) and chlorophyll-a concentration (Chla). We built an estimator based on in-situ data collected during the 2013 DeWEX cruise in the North-Western Mediterranean. To do so, we use a two-layer feed-forward network with sigmoid hidden neurons and linear output neurons, trained with Levenberg-Marquardt backpropagation algorithm. The result provides a reconstruction of pCO_2 distribution with a very good accuracy (coefficient of determination r^2 equals 0.84, Root Mean Square Error RMSE equals 14.4 µatm). The main challenge here, compared to other studies, was that we had only 1039 data to determine the pCO_2 estimator. Thus, the interest of this work is to demonstrate that mathematical relations can be determined relatively easily to obtain an estimation of pCO_2 distribution based upon measurements of in situ T, S and Chla. In fine, as satellite data of T, S and Chla are now available, remote sensing observations could be a great help to determine pCO_2 distribution on a global scale.

The Netherlands is subsiding whilst sea level is rising

Tanya Lippmann[1,2], Ko van Huissteden[1], Monique Heijmans[3]

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Land subsidence on drained peatlands is of growing concern in the Netherlands as well as other high latitude regions (Northern Eurasia, Northern America). Rewetting previously drained sites is proposed to halt subsidence and once again increase land surface height. However, rewetted sites are high methane emitters and a net GHG source even 20 years after re-wetting. An ideal management approach would counteract land subsidence and re-establish the peatland as a GHG sink.

The establishment of peat-contributing vegetation in low nutrient soils have been shown to emit significantly fewer greenhouse gases compared to those without peat-contributing vegetation. This finding is recent and has only been observed in short-term (<4 year) field experiments. Long-term field experiments and model simulations are necessary to quantify the relationship between peat-contributing vegetation and associated greenhouse gas emissions.

This study builds upon an existing belowground biogeochemistry model to now include competition between plant functional types. This study seeks to quantify the relationship between (non) peat-contributing vegetation and greenhouse gas emissions.

Two re-wetted peat sites are used for model validation; a nature reserve with peat-contributing vegetation and a re-wetted (only) former agricultural site with non-peat-contributing vegetation.

Decadal simulations comparing the role of sphagnum, Vaccinium oxycoccus (cranberry), Vaccinium myrtillus (European blueberry), and Typha latifolia on peat development and GHG fluxes will be presented.

These results show that the establishment of peat-contributing vegetation is capable of playing a significant role in restoring peatlands as a GHG sink whilst also counteracting land subsidence. Land planners must consider whether rewetted sites will be left as-is, converted to nature conservation or used for paludiculture. These results are of significance to all countries with drained peatlands.

KEYWORDS: peat, land subsidence, ecology, long-term, biogeochemistry

Oral Presentations for Session 4: Globally integrative studies

Conveners: Leonard Rivier

Regional changes in land-atmospheric CO2 exchange over recent decades using trendy DGVMs

Stephen Sitch, Geography, University of Exeter, Exeter, United Kingdom, presented by Michael O'Sullivan
TRENDY authors, Geography, University of Exeter, Exeter, United Kingdom

Land ecosystems currently moderate global climate change by absorbing over one quarter of the anthropogenic emissions of carbon dioxide (CO2) on average every year (Le Quéré et al., 2015). This CO2 land 'sink' is modulated by changing environmental conditions, including climate change and variability, atmospheric CO2, and Land Use and Land Cover Changes (LULCC). For the historical period, 1901-2017, outputs from a suite of Dynamic Global Vegetation Models (DGVMs), driven with observed climatology, are analysed. I will summarise recent studies using the TRENDY DGVM ensemble to quantify the global and regional mean, Interannual Variability (IAV) and trends in CO2 fluxes over the period 1990-2017, attribute to underlying processes (CO2, Climate variability and LULCC), and quantify the uncertainty and level of model agreement (Sitch et al., 2015).

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Sitch, S, P. Friedlingstein, N. Gruber, S. Jones, G. Murray-Tortarolo, A. Ahlström, S. C. Doney, H. Graven, C. Heinze, C. Huntingford, S. Levis, P. E. Levy, M. Lomas, B. Poulter, N. Viovy, S. Zaehle, N. Zeng, A. Arneth, G. Bonan, L. Bopp, J. G. Canadell, F. Chevallier, P. Ciais, R. Ellis, M. Gloor, P. Peylin, S. Piao, C. Le Quéré, B. Smith, Z. Zhu, R. Myneni Trends and drivers of regional sources and sinks of carbon dioxide over the past two decades, Biogeosciences, 12, 653-679, 2015.

Important Omissions in the Quantification of The Global Carbon Cycle

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Guang Zeng, NIWA, Wellington, New Zealand, Fabiano Ximenes, New South Wales Department of Primary Industries, Sydney, Australia, Donna Giltrap, Landcare Research, Palmerston North, New Zealand, John Zeldis, NIWA, Christchurch, New Zealand

The main components typically used in global carbon cycle calculations are the emissions from burning fossil fuels, cement production, and net land-use change, CO_2 uptake by the oceans and the CO_2 increase in the atmosphere. The difference between these more readily quantifiable terms is referred to as the residual sink. The size of this residual sink is often assumed to correspond to the increase in carbon stored in the terrestrial biosphere (ΔB) and used as a constraint in global earth-system models.

However, a global carbon budget with only these terms omits a number of important additional fluxes. They are cement carbonation, the fluxes into increasing pools of plastic, bitumen, and refuse in landfills after disposal of these products. Further, there are carbon fluxes to the oceans via wind erosion and non-CO_2

fluxes of methane and other volatile organic compounds and their intermediate break-down products. Carbon fluxes from the land to the oceans by river transport have also been only incompletely included in the overall budget. While the flux of dissolved inorganic carbon is added to estimated air-ocean exchange in deriving the reported ocean uptake, the fluxes of dissolved and particulate organic carbon, and the deposition of carbon in inland water bodies are not included.

Each one of these terms on its own is relatively small, but together they can constitute an important omission that significantly reduces the size of the inferred ΔB. It is estimated here that explicit inclusion of these fluxes would reduce ΔB from the currently reported 3.6 to 2.1 GtC yr^{-1} (excluding losses from land-use change). The implicit reduction in the size of ΔB has important implications for the inferred magnitude of current-day biospheric net carbon uptake and the consequent potential of future biospheric feedbacks that can act to amplify or negate net anthropogenic CO_2 emissions.

Top-down constraints on the North American carbon cycle from the first decade of the North American Carbon Program

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The North American atmospheric carbon measurement network has grown from a handful of sites in 2004 to more than 100 sites in 2017, thanks to the combined efforts of US agencies contributing to the North American Carbon Program, Environment and Climate Change Canada, and private investment in GHG monitoring. This unprecedented dataset informs spatially and temporally resolved emissions and uptake flux estimates and provides quantitative information about drivers of variability, such as rainfall and temperature. Recent advances in regional transport modeling and the development of flexible, high-resolution, inversion methods allow flux estimation at scales that are sufficiently fine to reduce the impact of aggregation errors and to linking inferred flux variability to underlying drivers. CarbonTracker-Lagrange (CT-L) is a flexible modeling framework that leverages these model developments and provides a platform for systematic comparison of data assimilation techniques and evaluation of assumed prior, model and observation errors. CT-L uses footprints from the WRF-STILT modeling system to relate atmospheric measurements to upwind fluxes and boundary values. Fluxes are adjusted using Bayesian or Geostatistical methods to provide optimal agreement with available observations. Footprints are pre-computed and the optimization algorithms are efficient. Thus, it is possible to explore a wide range of inversion scenarios designed to investigate sensitivity to model inadequacies, including errors in simulated atmospheric transport and boundary values, and to the mathematical construct of the optimization and various data weighting strategies. Multi-species data inform flux estimation by providing additional constraints to enable source/sink attribution. We are working to implement multi-species inversions for CO_2 flux estimation using CO_2 data along with $\delta^{13}CO_2$, COS and radiocarbon observations and for CH_4 flux estimation using data for various hydrocarbons. We will present a synthesis of North American CO_2 and CH_4 surface flux estimates spanning nearly a decade and with rigorously quantified uncertainties.

Comparing first results of the Sentinel-5 Precursor methane and carbon monoxide using TCCON data: ESA AO project TCCON4S5P

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The Sentinel-5 Precursor (S5P) was successfully launched on 13 October 2017 with the TROPOspheric Monitoring Instrument (TROPOMI) as the single payload onboard. It measures the Earth's reflected radiances from the ultraviolet to the shortwave infrared spectral range with a spatial resolution down to 7x7 km2 and has a daily global coverage. The S5P data will be made available to the S5PVT projects during the commissioning phase E1. The ongoing TCCON4S5P, project led by the Royal Belgian Institute for Space Aeronomy (BIRA-IASB) and supported by the TCCON community, was submitted as an answer to the ESA-AO (announcement of opportunity) call for the calibration and validation of the S5P mission. This project is focused on the geophysical validation of S5P methane (CH4) and carbon monoxide (CO) total column products using coinciding TCCON data from the whole network, which includes currently about 25 globally distributed stations. The proposed validation activity in this project will be carried out using the TCCON rapid delivery data for the first twelve months of the satellite data followed by a second phase where the focus will be on the continuous long-term validation during the operational lifetime of the satellite. In this presentation we propose to show the first validation results of S5P CH4 and CO products using TCCON data from the whole network provided there will be a sufficient number of satellite data available by that time. In addition, the presentation will give an overview and discuss the current status of the project.

EMSO ERIC

European Multidisciplinary Seafloor and water-column Observatory
European Research Infrastructure Consortium
A pan-European Distributed Research Infrastructure from Data to Services

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EMSO ERIC aims to promote science of excellence through a coordinated distributed infrastructure of deep-sea observatories serving marine scientists, offshore engineers, policymakers, industry and the public to understand the complex environmental processes.

EMSO became an ERIC in autumn 2016 and it is supported by eight Member states and by H2020 EMSO-related projects (i.e. EMSODEV and EMSO-Link). The EMSO ERIC mission is to establish a comprehensive and smart sensor system in water column, seafloor, and sub-seafloor environments. This distributed infrastructure composed of 8 Regional Facilities and 3 Test sites (Figure 1) and managed by Regional Teams, provides high-quality data and knowledge to understand key environmental processes that affect the complex interactions among the geosphere, biosphere and hydrosphere.

EMSO ERIC represents the European capacity to address benefits fulfilling the European societal scientific demands targeted in the EU´s H2020 Blue Growth Strategy. More specifically, EMSO ERIC will provide information and knowledge impact on:

- Climate Change and Ocean acidification.
- Appraisal of Economic Impact of Algae Blooms.
- Mitigation of Natural disasters in marine environment (i.e., volcanoes, landslides, earthquakes, tsunamis).
- Copernicus services, marine safety, marine resources, climate forecasting, etc.

EMSO ERIC provides different types of information and services though 5 Services Groups: Science, Engineering & Logistics, Data Management, Communication, and Industry & Innovation.

Posters for Session 4: Globally integrative studies

Cabauw 25 years of GHG measurements

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Arnoud Frumau, EMSA, TNO, Petten, Netherlands, Danielle Dinther, van, EMSA, TNO, Petten, Netherlands, Alex Vermeulen, ICOS Carbon Portal, Lund, Sweden, Pim Bulk, van den, EMSA, TNO, Petten, Netherlands

In-situ observations of greenhouse gas concentrations have been performed for 25 years at Cabauw, the Netherlands. The measurement system has been gradually extended and improved, starting with CO2 and CH4 concentrations from 200m a.g.l. in 1992 to vertical gradients at 4 levels of the gases CO2, CH4, N2O, CO including the CO2 isotopic species 13C and 18O. Moreover a 10 year record with a 2 level gradient for 222Rn as well as 14CO2 is available. In 2018-2019 significant expansion of the measurement site is foreseen including C2H6, 13CH4, NH3 and extending the reactive gases with NO, NO2 and O3. We would like to celebrate the 25 year anniversary with an historical highlight overview and an outlook for the next ten years.

Global terrestrial carbon sink in recent 36 years simulated using a remote sensing driven process-based diagnostic model

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Jingming Chen, International Institute for Earth System Sciences, Nanjing University, Nanjing, China, Liu Ronggao, Institute of Geographic Sciences and Natural Resou, Beijing, China

Global terrestrial carbon sink during 1981 to 2016 was simulated using a process-based diagonostic model BPES. Remotely sensed parameters (including leaf area index (LAI), clumping index, land cover) in conjunction with meteorological, CO2 and nitrogen (N) deposition data were used to drive the BEPS models at daily time steps. The estimated annual terrestrial carbon sink since 1981 using the model correlates well with the residual of the global carbon budget (Le Quere et al., 2017) ($R2^{=}0.56$, $RESE^{=}0.84$ Pg C /yr). The spatial and temporal patterns of simulate gross primary productivity (GPP) mirror those of remotely sensed solar-induced chlorophyll fluorescence well.

The accumulated global terrestrial carbon sink estimated by the BEPS model amounted to 95.4 Pg C during the study period, mainly driven by CO2 fertilization. Changes of LAI played the second role in enhancing global terrestrial carbon sink. Climate change had a negative impact on the global terrestrial carbon sink, owing to the larger increase of respiration than that of gross primary productivity. Carbon fluxes of terrestrial ecosystems in different regions exhibit difference in sensitivity to drought.

ICOS Carbon Portal: Elaborated products and services to support European carbon budget estimates

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ICOS Carbon Portal is the data center of the ICOS Research Infrastructure and the 'one stop shop' for ICOS data products. Carbon Portal is in charge of archiving and disseminating all ICOS measurement data. In addition, various elaborated data products, i.e. outputs of modelling activities based on ICOS observations, are compiled and distributed by Carbon Portal.

In order to facilitate the creation of such elaborated products by the research communities themselves, Carbon Portal provides access to a variety of datasets that can be used as prior and ancillary information in models as well as atmospheric measurement data, e.g. in form of the ObsPack CO_2 product GLOBALVIEWplus, for which the Carbon Portal has collected and processed contributions from the European laboratories.

Carbon Portal actively supports the EUROCOM project in a collaborative reanalysis of European CO_2 fluxes over the period 2006-2015. EUROCOM involves modellers from several European research institutes contributing results from a variety of inversion systems. Carbon Portal provides a platform for the collaborative analysis of the inversion results and eventually also for their further dissemination.

Interactive tools for visualization, comparison, and synthesis of data and elaborated products are hosted at the Carbon Portal website. A first test instance of a Virtual Research Environment, based on Jupyter Notebook, allows users to execute interactive statistical analyses and visualizations of modelling results, emission inventories, and ICOS data sets via a combination of pre-prepared and user-specific Python scripts.

On-demand calculation of atmospheric measurement station footprints is another service offered by Carbon Portal. This tool combines natural greenhouse gas fluxes from biospheric models and anthropogenic emissions with the lagrangian transport model STILT, in order to illustrate the time evolution of the geographical origin of the greenhouse gas signal that is measurable at a specific location, providing information for the design and assessment of measurement strategies.

Pan-Eurasian Experiment (PEEX) program and GlobalSMEAR initiative

Lappalainen Hanna, INAR, University of Helsinki, Helsinki, Finland, presented by Päivi Haapanala

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The Pan-Eurasian Experiment (PEEX) program was initiated as a bottom-up approach by the researchers coming from Finland and Russia in 2012. The main scientific mission of the PEEX program is to understand large-scale feedbacks and interactions between the Earth surface–atmosphere continuum in the changing climate of northern high latitude and in China. The PEEX Science Plan[1] addresses the scientific aims and large-scale research questions of the program. PEEX has also introduced a concept design for a seamless modelling platform and ground-based in situ observation systems for detecting land–atmosphere and ocean–atmosphere interactions.

PEEX is currently carrying out its research activities on a project basis and promoting the research infrastructure framework GlobalSMEAR outside Europe, especially in Russia and China. The GlobalSMEAR is an approach towards integrated Global Earth observatory[2] initiated by Academician Markku Kulmala and coordinated by Institute for Atmospheric and Earth System Research of University of Helsinki. The SMEAR (Station Measuring the Earth Surface–Atmosphere Interactions) concept is supporting the implementation of the GlobalSMEAR initiative and offers an observation platform that provides continuous, comprehensive environmental information from local level up-to the global Grand Challenges. GlobalSMEAR enables upgrading of the existing stations by adding a site-specific SMEAR-concept instrument setup together with technical guidance together with a detailed data exploitation / science plan. The prototype of the most well-equipped station implementing the SMEAR concept is the SMEAR II (a Station for Measuring Ecosystem-Atmosphere Relations) in Hyytiälä, Finland.

PEEX has also just recently released its Silk Road agenda[3] together with the Digital Belt and Road (DBAR) Initiative. The near-future challenge is to achieve a successful integration of the methodological approaches of the socio–economic research to environmental sciences and to release the 1st scientific overview of the PEEX region.

[1]Lappalainen et al. 2016, Atmos. Chem. Phys.
[2]Kulmala 2018, Nature
[3]Lappalainen et al. 2018, Big Earth Data

Combined balloon, aircraft, surface and remote sensing greenhouse gas measurements at Traînou supersite, France

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Céline Lett, CEA - LSCE, Gif-sur-Yvette, France, Michel Ramonet, CEA - LSCE, France , Cyril Crevoisier, CNRS - LMD, Palaiseau, France, François Danis, CNRS - LMD, Palaiseau, France, Thorsten Warneke, Institute of Environmental Physics, Bremen, Germany, Christof Petri, Institute of Environmental Physics, Bremen, Germany, Yao Té, CNRS - LERMA, Paris, France, Pascal Jeseck, CNRS - LERMA, Paris, France, Marc Delmotte, CEA - LSCE, Gif-sur-Yvette, France, Olivier Laurent, CEA - LSCE, Gif-sur-Yvette, France, Léonard Rivier, CEA - LSCE, Gif-sur-Yvette, France, Philippe Ciais, CEA - LSCE, Gif-sur-Yvette, France

The Traînou atmospheric tall tower for greenhouse gas (GHG) monitoring, located approximately 100 km south of Paris, is the only site in Europe where both ICOS surface and TCCON total column networks are operated: it benefits from a tall tower setup for in-situ GHG measurements at 5, 50, 100 and 180 m height, and is equipped with a ground-based FTIR (TCCON-Orléans) for total column measurements. In addition, an aircraft measurement program allows monthly flights to measure GHGs between 100 and 3000 m above the tall tower.

In 2016, we started an AirCore program at Trainou making possible to sample and derive GHG vertical profiles up to 30 km above the mean sea level for moderate costs and logistics. Thus, in addition to the surface and remote sensing measurements, several intensive field campaigns were performed: lightweight AirCores were flown and analyzed to retrieve the GHG profiles (CO_2, CH_4, CO and N_2O). Since April 2017, a compact FTIR instrument (EM27/SUN) measuring total column is also deployed either at the tall tower for comparison purpose with the TCCON spectrometer or at the estimated landing sites of the launched AirCores during intensive campaigns.

The aim of the campaign like HALO/CoMet in May 2018, is to demonstrate the feasibility of combining surface, airborne, balloon-based and remote sensing total column measurements of GHG at the same location. The instrumental synergy used during the campaigns leads us to be in a unique and innovative position for analyzing spatio-temporal coherence between various measurement techniques dedicated to the GHG survey.

The proposed poster describes in details the AirCore measurement technique used by LSCE and LMD. We also present the dataset acquired from the different campaigns that merge observations from surface, aircraft, and AirCore measurements at the Traînou supersite.

First measurements of CO2, CH4, CO, and 222Rn at the new Atmospheric Observatory Tower in Ispra, Italy

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Accurate measurements of atmospheric greenhouse gas (GHG) concentrations are essential for "top-down" emission estimates at regional to continental scales. Since end of 2016, the Joint Research Centre (JRC) of the European Commission is operating the new Atmospheric Observatory at Ispra (45.8147°N, 8.6360°E, 210 m asl) at the South-Eastern border of Lake Maggiore in a semi-rural area at the North-Western edge of the Po Valley. The Atmospheric Observatory includes a 100 m tower and a laboratory with instrumentation for high accuracy continuous monitoring of carbon dioxide (CO2), methane (CH4) and carbon monoxide (CO) at 40m, 60m and 100m above ground level. GHG observations are complemented by continuous radon (222Rn) observations and meteorological measurements (wind speed and direction, air temperature, relative humidity and air pressure). The Atmospheric Observatory in Ispra contributes to the ICOS station network and it is currently in "step 2" of the ICOS labelling process.

Here, we present the CO_2, CH_4, CO and 222Rn measurements since end 2016, including an analysis of the data quality, following the ICOS ATC QA/QC procedures. Moreover, we present preliminary results from the application of the ATC spike detection algorithm in order to filter out measurements affected by nearby local GHG sources.

The CzeCOS ecosystem stations network

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The Global Change Research Institute of the Czech Academy of Sciences (CzechGlobe) has established a well-equipped network of ecosystem stations with modern instrumentation for greenhouse gas fluxes, eco-physiological, plant-physiological and micrometeorological studies. The research infrastructure CzeCOS (Czech Carbon Observation System) is included in the Czech National roadmap of major research infrastructures. The network covers the representative terrestrial ecosystems of the Czech Republic (coniferous forests, deciduous forest, mixed floodplain forest, grassland, wetland, cropland and poplar plantation).

The floodplain forest has been influenced by anthropological impact of water management during the last decades and represents conditions similar to those expected during the climate change (drought). The 37-year old Norway spruce forest represents typical Central European coniferous forest of higher altitudes, while the 113-year old Norway spruce forest (located at low latitude) allows investigating the drought influence on the ecosystem. The wetland LTER station is located in the UNESCO MAB reservation. The deciduous forest is managed European mature beech stand with tree species composition close to natural. Further two ecosystems represent the typical managed ecosystem, the grassland (mowed once per year) and the cropland (intensively managed). The poplar plantation is used for investigation of management for effective biomass production for energetic purposes. The floodplain forest, Norway spruce forest and wetland stations are proposed as ICOS sites.

The CzeCOS ecosystem station network enables detailed research to be conducted on topics like carbon balance and energy fluxes of different ecosystems, the impact of extreme weather conditions (drought, floods, winter storms, etc.) on physiology, production and making predictions of future behaviour of ecosystem under expected climate change. The poster shows specific results from the sites and outline the importance of the regional/national network for improving our knowledge about the exchange of matter and energy fluxes at different ecosystems.

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The Long-Term Micrometeorological and Boundary Layer Measurement Program at the ICOS-D Atmospheric Observatory Lindenberg

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The 99-m tower at the boundary layer field site Falkenberg of the Meteorological Observatory Lindenberg – Richard-Aßmann-Observatory (MOL-RAO) of the Deutscher Wetterdienst (DWD) is part of the ICOS atmospheric observation network in Germany since October 2015. Currently concentration measurements of CO2 and CH4 are taken at four heights (2.5, 10, 40, and 99 m) com-plemented by air samples for radon analysis which are collected at the top level of the tower. The accompanying meteorological data originate from the comprehensive micrometeorological and boundary layer measurement program which is performed at MOL-RAO since 1998. Located in the North-East of Germany the landscape around MOL-RAO is a mixture of (mainly pine) forests and agricultural farmland with small lakes and villages embedded. To characterize atmospheric boundary layer structure and processes and the interaction of the atmosphere with this typical heterogeneous land surface, the boundary layer measurement program of MOL-RAO comprises

- operation of the special boundary layer field site over grassland, including measurements of atmospheric profiles at towers up to 99 m height, of soil parameters down to 1.5 m depth, of short-/longwave radiation, and of the turbulent energy and momentum fluxes,
- operation of a sodar / RASS and an infrared Doppler Lidar,
- continuous micrometeorological measurements at a forested site,
- operation of a large-aperture optical and a microwave scintillometer for the estimation of area-averaged sensible and latent heat fluxes.

Complemented by free-troposphere information from radar wind profiler / RASS measurements and from radiosoundings four times a day, a long-term quality-controlled data set covering a wide range of meteorological situations has been generated, which is used in DWD for regular and process-oriented validation of numerical weather prediction models. The paper will present the measurement and data quality control program which might be a valuable background information for the ICOS measurements at Falkenberg.

Measuring atmospheric argon at Jungfrau East Ridge to estimate the oceanic influence on atmospheric oxygen using a mass spectrometer

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Due to the high elevation of 3700 m a.s.l., Jungfrau East Ridge Station, which is part of the High Altitude Research Station Jungfraujoch in Switzerland, is mainly above the planetary boundary layer and receives predominantly well mixed air masses from the free troposphere. The footprint covers Western and Central

Europe and a significant part of the Atlantic and the Mediterranean Sea. It is therefore ideal to estimate the partitioning between the biospheric and oceanic carbon sink of the northern hemisphere by measuring atmospheric carbon dioxide (CO_2) and molecular oxygen (O_2). In these calculations, the O_2 outgassing from the ocean is often considered to be constant over time, which is not quite true due to the temperature dependency of the gas solubility in ocean water. To get a better estimate of the gas solubility in ocean water, argon (Ar) can be used as a tracer. As a noble gas, changes in its atmospheric mole fraction are mainly driven by oceanic uptake and outgassing. With the known Henry's law constants for Ar and O_2, it is possible to use the Ar measurements to estimate the oceanic O_2 outgassing. Using the calculated O_2 outgassing values instead of a constant might improve the estimates of the partitioning of the biospheric and oceanic carbon sink. We determine Ar and O_2 continuously based on Ar/N_2 and O_2/N_2 ratios with a mass spectrometer (PrecisION by Elementar, Manchester, UK) that was installed at the Jungfrau East Ridge station in April 2018. We will present the design and layout of the instrument and the sampling line as well as their characterization.

An update on CarbonTracker Europe: Global carbon fluxes up to 2018 and coupling with the ICOS Carbon Portal

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We will present the latest results of CarbonTracker Europe, a data assimilation system that uses atmospheric carbon dioxide concentration measurements to estimate carbon fluxes from the terrestrial land and ocean. CarbonTracker Europe 2018 (CTE2018) uses the anthropogenic fossil fuel emissions inventory EDGAR and outputs of biosphere model SiBCASA ran together with the GFED4 biomass burning product. We have assimilated observed CO_2 mole fractions from the latest GlobalViewPLUS (3.2/4.0 release) to optimise our flux estimates after transporting the atmospheric carbon dioxide concentrations using the model TM5 with 1°x1° zoomed regions over North America and Europe. Here, we extend the previous inversion of CTE2017 to include 2017 and use the results to assess recent changes to the global carbon balance.

We also showcase the capability of the ICOS Carbon Portal to provide the data necessary to run CarbonTracker Europe. The download of this data has been included in the model set-up, demonstrating automated access to a vast amount of research data from all ICOS thematic centres via an easy-to-use API. We uploaded the CarbonTracker Europe results to the Carbon Portal after completing the simulation, evidencing the ease and convenience of the system as a data exchange platform. Metadata are rigorously maintained throughout the process, allowing proper recognition of the work of data providers and improving reproducibility for modellers.

Seasonal and interannual variability of CO_2 fluxes: 14 years of eddy covariance measurements in Basel, Switzerland

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Back in May 2004 CO_2 flux (FC) measurements using the eddy covariance method were started in Basel Klingelbergstrasse (BKLI) and are conducted continuously since then. In 2009 a second urban flux site at

Aeschenplatz (BAES) was added. For the gap-filled FC time series horizontal averages were calculated. This improves the significance and comparability of measured fluxes and demonstrates the need of adequate weighting by horizontal averaging in such heterogeneous urban environments, especially for the derivation of cumulative quantities like the annual net ecosystem exchange. FC is presented with respect to diurnal and seasonal cycles as well as interannual variabilities. FC shows a large interannual variability in times of high source activity (e.g., during the day and in winter). In contrast, a relatively constant background flux of 5 µmol $m^{-2}s^{-1}$ is found during periods of low source activity. The long-term trend of FC is mostly superimposed by the large temporal variability and is found to be around -5% over 10 years.

Retrieval of methane vertical information from TCCON FTIR spectra

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The Total Carbon Column Observing Network (TCCON) is an international network to use the ground-based Fourier Transfer Infrared Spectrometer (FTIR) to record the direct solar spectra in the near-infrared range and to retrieve total columns of greenhouse gases with a high precision in the atmosphere, including methane (CH4). Currently, there are about 25 TCCON sites around the world. The GGG2014 code is the standard TCCON retrieval software performing a profile scaling retrieval, so that the TCCON products only provide the total column averaged CH4 (XCH4). Earlier studies have shown that the tropospheric and stratospheric XCH4 from the TCCON product could be successfully obtained by a proxy method, because hydrogen fluoride (HF) and nitrous oxide (N2O) have good relationships with CH4 in the stratosphere.

In the framework of the H2020 RINGO project, we employ the SFIT4 algorithm to retrieve the CH4 vertical profile from TCCON spectra (SFIT4TCCON) on six TCCON stations (Ny Alesund, Sodankyla, Bialystok, Bremen, Orleans, Reunion Island). The retrieval strategy of the CH4 vertical retrieval was investigated. The degree of freedom for signal of SFIT4TCCON retrieval is about 2.0-2.4, and independent partial columns of CH4 are obtained in the troposphere and in the stratosphere. The averaging kernel shows that the SFIT4TCCON CH4 retrieval has a good sensitivity in the vertical range from the surface to the middle stratosphere (about 35 km). The time series and correlations of the XCH4 from the standard TCCON and SFIT4TCCON measurements in 2016-2017 on six sites will be shown. In addition, the tropospheric and stratospheric XCH4 from the SFIT4TCCON measurements are compared with the XCH4 from the proxy method (HF and N2O). The comparison between the SFIT4TCCON retrieved CH4 profiles and the AirCore measurements at Sodankyla will also be shown.

Contribution of fire decline to the global carbon budget over the last decade

Yi Yin

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A decline of nearly a quarter of the global burned area has been observed over the past 18 years, with the most substantial decrease in the savanna ecosystem. These reductions are likely due to shifts in land-use changes as most declines are related to agricultural expansion and intensification. The estimates of fire carbon emissions, however, are complicated by fuel load and combustion efficiency that are further mediated by land use change and climate variabilities. Here we estimate the global fire carbon emissions from 2001 to 2016 using a data-constrained terrestrial carbon cycle model (CARDAMOM), in which the key carbon cycle parameters are constrained by observations of leaf area index, pan-tropical biomass, and soil carbon, while fire carbon emissions are explicitly constrained by atmospheric CO inversions that also informs about the combustion completeness given the modelled fuel load. We then diagnose the relative contributions due to human interference and climate variability using sensitivity simulations and further analyze their legacy impacts on the global carbon budget during the last decade.

Oral Presentations for Session 5: Data management and quality

Conveners: Per Öster, Zhiming Zhao

Efficient and effective management of data and data products is critical for modern climate science and a key responsibility for ICOS and other research infrastructures. Data management is concerned not only with the practical storage and serving of data, but also encompasses (semi-automated) data quality checking, metadata generation (including assignment of persistent identifiers for long-lived datasets), provenance recording (including for version management, attribution and accounting) and cataloguing (including exposing data to other services to increase the visibility and accessibility of research assets). 'Data' in this context are not limited to scientific observations and measurements, but also all derived products, metadata, code, logs and other information objects that must be properly curated. Thus, this session is concerned with the requirements and state of the art of data management and data quality checking in all parts of the ICOS research infrastructure and in conjunction with other environmental science initiatives and infrastructures with which ICOS collaborates.

ICOS ATC labeling process: helping stations to reach ICOS standards through quality control and two-way communication

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A monitoring station officially becomes ICOS after a three step process : 1- Formal application and site location assessment, 2- Station construction, Initial test period, evaluation, optimisation, 3- Formal decision of the station integration by the ICOS ERIC general assembly. Here, we present in particular the process happening during the initial test period where the station data are controlled, evaluated and optimised when necessary. Two-way communication between the stations and the ATC is essential and allows progress on both sides : optimisation of the station flow, optimisation of the ATC protocols and tools. This period is illustrated through examples from the eleven ICOS atmospheric labeled stations. We present also new quality control protocols that have been developed during that time with the station feedback.

The AmeriFlux Network Data Management System

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The number of sites that are part of AmeriFlux has grown considerably, covering from the Amazonian rainforests to the North Slope of Alaska. The new data processing and QA/QC pipeline in the AmeriFlux data management system has been modernized to enable semi-automated QA/QC processing and tracking of data issues. The AmeriFlux Data Team has also been working to modernize the data processing pipelines and data products distributed via our AmeriFlux and FLUXNET sites. The new products are designed to support data contributors and data user communities and enable more frequent data processing. This work on data standardization, data identifiers, data pipelines, and FLUXNET is in close collaboration with the ICOS community. This presentation describes the current AmeriFlux system, the collaboration, and future opportunities for collaboration.

Development of the ICOS data portal integration into the cloud in the framework of the ENVRIplus ‘Data for Science’ Theme

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As an integral part of ICOS, the Carbon Portal uses Semantic Web technologies to provide full metadata for all the ICOS data products, on behalf of the three themes of ICOS. This allows researchers to explore the accumulated ICOS data and retrieve specific datasets. ICOS is of course part of a wider ecosystem of environmental research infrastructures (RIs).

Cross-RI search is critical for multi-disciplinary research, and while the Carbon Portal provides essential context and access to ICOS data products, its capabilities must be linked with those of other infrastructures and pushed out to a wider open research cloud that researchers can explore based on scientific needs. This can be achieved by joint resource catalogues and extensive association networks (through the same linked data networks that ICOS CP is built upon). These can direct investigators to ICOS data and services via semantic tools.

The 'Data for Science' theme of ENVRIplus develops shared technology solutions to common problems of environmental science RIs. The ENVRI approach is provide intelligent knowledge infrastructure to ensure the discoverability of resource metadata on a scientific rather than institutional basis, while still retaining proper attribution to individual RIs, data centres and research groups. For this we developed services such as the ENVRI Knowledge Base that aggregates data about RI architecture, data and services, and exposes such information as Linked Open Data. Other ENVRI services include the Flagship Catalogue Service that promotes key data products of different RIs using standard metadata schemes tailored for environmental science and DRIP for automated provisioning and deployment of data services (e.g. data subscription) in cloud environments.

We discuss how semantic and technical linking between these services and the Carbon Portal data services can help expose ICOS services to a wider scientific community as part of an emerging cloud of RI data and services.

Forest net ecosystem CO_2 exchange in sloping terrain as derived by eddy covariance

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The experimental ecological study site Bily Kriz (49°30'N, 18°32'E; 800–900 m a.s.l.) is located in the Moravian-Silesian Beskydy Mountains, the Czech Republic. The experimental forest is a ~ 40 years old Norway spruce (Picea abies/L./, Karst) monoculture with a leaf area index of ~ 9 $m^2\ m^{-2}$ in 2016. An EC tower is situated there at a ridge on a steep roughly south oriented planar slope with a regular inclination of 13°. The ridge and slope force the flow above the canopy in two main regimes, namely upslope and downslope. Recently, an additional below-canopy EC system was installed for providing readings of the standard deviation of vertical wind (σ_w) within the canopy. The correlation of σ_w between above and below canopy air masses remarkably differs for the cases of decoupling and the cases of full coupling. Thus, once an objective site-specific threshold in this σ_w correlation is experimentally determined, it can be used as an EC flux filtering approach.

The ultimate goal of the overall site setup is to provide defensible annual sums of forest carbon exchange in topographically complex terrain. This particular study aims to assess the applicability of the introduced two-level filtering in such terrain. Furthermore, it aims to evaluate the effect of the two-level filtering on the above canopy measured EC CO_2 fluxes. We use an initial 1-year example period (August 2017-July 2018) to demonstrate first results of this study. The data suggest that the two-level filtering is applicable also in such complex terrain. Furthermore, the two-level filtering increases the magnitude of both nighttime and daytime above-canopy CO_2 fluxes in comparison to single-level filtered CO_2 fluxes. This effect will be ultimately discussed by comparing the annual sums of forest carbon exchange based on single-level filtered and based on two-level filtered measured CO_2 fluxes.

Posters for Session 5:
Data management and quality

Travelling cylinders as a quality control tool in ICOS atmospheric station network

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The quality control (QC) of European-wide ICOS atmospheric station (AS) network is performed by several tools and levels from data checking algorithms to station audits. Travelling QC cylinders is a method having already a long history in measurement networks like WMO-GAW and InGOS. Now the travelling cylinders approach is tested in ICOS ASs; do these cylinders give additional value for QC that is not otherwise achieved and is the amount of additional work in line with the QC benefits. The role of separate QC cylinders in ICOS is different than in other measurement networks, since all the ASs are using centrally prepared calibration gases. When the calibration gases are consistent, the role of travelling QC cylinders is more to evaluate the performance and expertise of AS and its personnel than to intercompare the level of measurements due to inconsistent calibration gases.

The instrumentation for greenhouse gas measurements in ICOS ASs is quite uniform due to strict demands for measurement precision. Also each individual instrument is tested before the approval for ICOS AS use. However, instrument's performance may decline by age, which is very difficult to observe from ambient air measurements. With calibration gases the principle is the same. Gas concentrations inside the cylinder may drift by age, and as the lifetime of a gas cylinder is several years, the drift is difficult to observe before the recalibration at the end of its lifetime. To assess this kind of changes in AS's performance, the travelling cylinders are useful QC tool and difficult to replace. This approximately a one year lasting test period with a few ICOS ASs has so far showed good results, i.e. high measurement performance of the evaluated stations. However, to maintain the high data quality of the growing AS network, broad set of QC tools is essential.

ICOS Data Model to FAIR Information

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ICOS is collecting a huge amount of data covering a large variety of environmental parameters across Europe. To present the data following the FAIR principles, the data has to be put in their context. We present a holistic view how to model the data flow to address four main pillars to provide meaning, context and traceability. First a bespoke ICOS vocabulary / ontology is created to represent measurements and meta data for the research infrastructure but taking into account the specific aspects of three domains (ocean, ecosystems, and atmosphere). This will include people, institutions, location, funding bodies etc. Secondly special attention is paid to describe the hardware (instruments and sensors) and the applied conversion, configuration and translation to measure the physical phenomena to provide a long term provenance for raw data up to advanced data products. Thirdly we link the data in a generic way to other semantic standards for information exchange. This makes the collected data set future proof and long term usable. As an example, a mapping to the European INSPIRE GeoDCAT is shown. And finally the fourth pillar addresses the problem how different snap shots of data including configuration files, methods, calibration, hardware information etc., which may change over time, can be reproduced. An implementation of a Universally unique identifier (UUID) with a persistent identifier (PID) like a digital object identifier (DOI) is presented to ensure a long-term perspective of data reproduction for scientific publications.

The presented model provides a flexible and easy to use interface to share data and meta-data which is already collected and stored by the ICOS community. The PID's provide a tool for humans and machines to find and exchange data. The model based on these four topics ensures that ICOS data adhere to the FAIR (findable, accessible, interoperable, reusable) Data Principles.

Diurnal patterns, seasonality and ebullition: A comparison of gap-filling strategies for closed-chamber CH4 measurements to derive a "best-practice" approach and give implications for future studies

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Due to their operational simplicity allowing for spatially distinct measurements as well as their low costs and power consumption, manual closed-chamber systems are widely applied for obtaining ecosystem CH4 emissions. This is in particular the case for peatlands, which represent a hot spot for CH4 release. However, CH4 emission estimates based on periodically conducted chamber measurements are prone to a high temporal uncertainty, mainly related to the excessive filling of long gaps. Hence, diurnal and seasonal measurement frequencies as well as the applied gap-filling strategy are crucial factors, influencing the reliability of derived CH4 emissions.

To date no comprehensive analysis of the influence and interactions of these factors has been performed, nor does a widely accepted standard procedure exist. As a result, it remains largely unclear whether CH4 emission estimates, resulting from closed-chamber measurements are comparable or not and to which extent differences in measurement design and gap-filling add to the overall uncertainty of derived emission factors.

Here, we present continuous automatic closed-chamber CH4 measurements during the year 2015 for two peatlands (Germany and Poland), which are used to compare commonly applied gap-filling approaches. The performance of gap-filling strategies was evaluated by comparing gap-filled with continuously measured CH4 fluxes and their resulting emission estimates.

Out of the different gap-filling strategies, interpolation and empirical modeling were most suitable. Machine learning approaches performed weaker, most likely because they require a greater amount of measured input data hardly being achieved by using discontinuous manual-chamber measurements. Compared to monthly or fortnightly measurements, the precision of CH4 emissions is substantially improved when applying a weekly measurement frequency. However, multiple measurements per day better reflect the average daily flux and thus reduce the potential bias of derived CH4 emission. Thus, a lower seasonal measurement frequency could partially be compensated by enhancing the number of diurnal measurements.

ICOS: where the hack is my/your data?

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The ICOS Carbon Portal (CP) is the data management and distribution center of ICOS. The CP core activities include our discovery services that allow prospective ICOS end users to search, visualize and download ICOS data products - but in addition to these highly visible activities, the CP is responsible for the development & operation of a number of very important basic services concerned with the ingestion, curation, archiving and overall management of the ICOS data holdings.

The poster will summarize the main functionalities of the Carbon Portal operations, including:

* long-term archiving (in the cloud) of all ICOS data and associated metadata from raw data to elaborated data products.

* web-based services for ICOS data discovery, including an advanced search interface, on-the fly interactive visualization and data download, that ensures the communication of the ICOS data licence, data usage count and provides the users with the correct attribution information

* our RESTful services for data uploaders, including automated metadata collection and allocation of persistent identifiers

* the ICOS cataloguing service & implementation of the RDF/OWL-based metadata ontology for ICOS that opens ICOS data up to other portals and portals of portals, and the EOSC

* provisioning of dynamically created “landing pages” for data, data content types and measurement stations – formatted that give access to data and its associated relevant metadata to be interpretable by both humans and computer-based processes

* Support services for internal ICOS users, modelers and other end users, including provision of on-demand cloud data processing and virtual research environments

N2O flux response to meteorological solicitations and farming practices in a sugar beet crop

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Using the eddy covariance technique, half-hourly N2O fluxes were measured over a sugar beet crop (Terrestrial Observatory of Lonzée, BE, ICOS site level 2) between March and October 2016. Several parameters of data quality control tests were modified to suit the characteristics of N2O. The u* filtering threshold was determined based on CO2 data as the procedure could not be implemented using N2O fluxes. The uncertainty on N2O fluxes was assessed for several aspects of data treatment (total random uncertainty, spectral correction, u* filtering, gap-filling), which were combined to determine the uncertainty on the budget.

N2O flux variability was characterized by three peak episodes during the experiment, interspersed with background fluxes. These events were driven by several variables, depending on the time-scale. The more time had passed after fertilization, the lower the potential for high fluxes was, and by the end of the crop season, only background flux was recorded. The soil water content at 5 cm was identify as the single trigger of N2O emission bursts, while intraday oscillations were positively correlated to the variations of surface temperature.

For the first time, an inhibiting effect of surface soil disturbance (seed-bed preparation) on N_2O fluxes was observed, which delayed the start of the following emission peak. This observation combined to the synchronicity between surface temperature and the oscillations of N_2O fluxes supports the hypothesis of a N_2O producing microbial community located in the topmost soil layer.

Between fertilization and harvest, the crop emitted 6520 (± 908) µmol N_2O m-2 which corresponds to an EF of 1.3 % - slightly above the IPCC estimate. Our results stress the importance of measuring N_2O exchanges in fertilized crops, as it weighed for 20% of the GHG budget.

Homogeneous data-reprocessing and full synthesis of eddy-flux measurements in French ecosystems: 1999 - 2015

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The attribution of the significant inter-annual variability of long lived greenhouse gas (GHG) fluxes, between edaphic, meteorological variables and ecosystem management parameters - independently or in interaction, evolving as a long term drift or as extreme events - remains uncertain. Our research aims to quantify the potential impact of climatic drifts or anthropogenic and meteorological events on ecosystem-atmosphere exchanges of French sites by analyzing the long series (at least continuous 9 years, between 1996 and 2015) of eddy covariance (EC) fluxes.

We firstly performed a homogeneously repost-processing of the raw EC data across 5 sites: three forest ecosystems (deciduous broad-leaved FR-Fon, evergreen broadleaved FR-Pue, and evergreen coniferous FR-Br), one extensive grassland (FR-Lq2) and one cropland (FR-Aur). These data, in terms of net ecosystem exchanges (NEE), gross primary production (GPP) and ecosystem respiration (Reco) were put together with the corresponding climatic and edaphic data and with the carbon stock inventory for an homogeneous statistical analysis and comparative interpretations.

The standard protocol, excluding any Nakai's corrections, helped to reduce the influence of the methodology and experimental design on the temporal and spatial variability. The methodology adopted finally used 35% on average of flux data for all sites. Based on the first analysis of reprocessed data from the forests, no significant long term evolution of NEE, Reco and GPP through the studied periods despite [CO_2] increase and long term change observed in environmental parameters. Combining all years, a respiration limitation at high air temperature was observed on the forest sites, with a LAI dependency for deciduous ecosystems, and REW dependency for evergreen southern sites. A dominant effect of air vapor stress, compared to edaphic stress was observed on GPP response to PPFD in the deciduous northern forest, significantly decreasing with VPD increase.

Flagging efficiency of different eddy covariance quality control schemes

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Eddy covariance (EC) is one of the most precise and direct approaches for measurements of matter and energy fluxes on ecosystem level with high temporal resolution. Although it has been applied for several decades by now, its methodology has not yet been standardized. This is mostly due to the concurrent development of methods by multiple scientific teams and different methodological requirements for each setup in given type of ecosystem. EC data processing chain consists of many dependent steps, e.g. coordinate rotation, covariance computations, flux corrections, quality control (QC), gap-filling and aggregation. In this contribution we focus on QC step that is one of the less standardized ones. Acknowledging the need for flexibility we present a software solution that allows application of multiple automated QC filters and tests but at the same time facilitates complete documentation of the QC process to achieve data processing reproducibility and transparency. The main aim is to compare three different QC schemes, i.e. 1) minimal QC scheme (only standard steady state and integral turbulence characteristics tests included), 2) complete QC scheme (all filters and tests available in the software applied) and 3) proposed recommended QC scheme (only options with maximum flagging efficiency included), applied to multiple site-years. QC filters and tests exclude spurious data and therefore improve dataset quality while increase of data exclusion fraction leads to increase of yearly sum uncertainty. Efficiency of each QC scheme will be thus evaluated from the point of view of maximum detection sensitivity for spurious measurements and minimization of yearly sum uncertainty.

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Oral Presentations for Session 6: Regional efforts to constrain the global C cycle

Conveners: Ana Bastos, Philippe Ciais

The global stocktaking under the Paris Agreement requires reliable and up-to-date information about global and regional green-house gas budgets and their component fluxes to be provided to societies and policy-makers.

The session invites contributions focusing on regional/basin level carbon budgets (CO2, CO, CH4) in land and ocean as well as their variability. The session is seeking contributions from the broader research community towards a second global assessment “REgional Carbon Cycle Assessment and Processes” (RECCAP-2) supported by the Global Carbon Project. Innovative approaches to improve understanding of both natural and anthropogenic fluxes and their anomalies at regional scales are welcome, as well as studies highlighting the potential of multiple data streams to produce regularly updated regional land and ocean carbon budgets, consistent with global budgets.

Tundra landscape heterogeneity, not inter-annual variability, controls the decadal regional carbon balance in the Western Russian Arctic

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Across the Arctic, the net ecosystem carbon (C) balance of tundra ecosystems is highly uncertain due to substantial temporal variability of C fluxes and to landscape heterogeneity. We modeled both carbon dioxide (CO_2) and methane (CH_4) fluxes for the dominant regional land cover types in a sub-Arctic tundra region in northeast European Russia for the period of 2006-2015 using coupled biogeochemical and permafrost models. Modeled net annual CO_2 fluxes ranged from -300 g C m^{-2} y^{-1} [net uptake] in a willow fen to 3 g C m^{-2} y^{-1} [net source] in dry lichen tundra. Modeled annual CH_4 emissions ranged from -0.2 to 22.3 g C m^{-2} y^{-1} at a peat plateau site and a willow fen site, respectively. Interannual variability over the decade was relatively small (20-30%) in comparison to variability among the land cover types (120-225%). Using high-resolution land cover classification, the region was a net sink of atmospheric CO_2 across most land cover types but a net source of CH_4 to the atmosphere due to high emissions from permafrost-free fens. Using a lower-resolution for land cover classification resulted in a 20-65% underestimation of regional CH_4 flux and smaller (10%) overestimation of regional CO_2 uptake, leading to an overall overestimation of the regional GHG sink by 90% due to the underestimation of wetland extent by 60%. Accurately capturing the relative fraction of uplands versus wetlands was key to determining the net regional C balance but required high (<25-30 m) spatial resolution.

Regional maps of ΔfCO2 and ocean acidification along the Norwegian coast

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In order to slow down climate change it becomes increasingly important to monitor every country ́s contributions to the global effort of reducing emissions. For tracking changes in a country ́s carbon emissions by using atmospheric inversions, it is important to include high precision estimates of air-sea CO_2 gradients along its coasts. Coastal oceans play a big role in the overall air-sea CO_2 exchange through their high, small-scale. The demand of a high spatial resolution in combination with the still poor data coverage results in substantive difficulties when estimating the surface ocean fCO_2 in these regions. At the example of the European shelf seas we present a method to produce monthly maps of fCO_2, the air-sea disequilibrium and pH. We use a MLR based on a set of driving variables, such as SST, SSS and chl a concentration,, atmospheric xCO_2, the already existing fCO_2 field in the adjacent open ocean and surface ocean fCO_2 observations. Our approach minimizes the offset at the overlap with the open ocean product and is easily applicable to different coastal regions.

Networking in Carbon Observations: Looking back, Scoping Forward

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Networks of ground-based and in-situ observations for carbon stocks, greenhouse gas (GHG) concentrations, and carbon fluxes are required to ensure traceability and reliability of satellite (e.g. OCO2, Landsat) and other remotely sensed retrievals; they are also necessary for developing, understanding, validating, and improving analyses, predictions, and ecosystem models. Satellite retrievals must be consistent with in-situ observations, including WMO/GAW, NOAA's GHG networks, Fluxnet data, and ocean time-series sites. CONTRAIL, CARIBIC, and, soon, IAGOS, are able to get periodic vertical profiles of GHGs at a number of sites globally. In this presentation, we highlight advances in collecting and assessing carbon cycle information assembled from previous decades of coordinated in-situ and remote observations across North America, focusing on findings from the 2nd State of the Carbon Cycle Report (SOCCR2), a U.S. Global Change Research Program Sustained Assessment product scheduled for release in late 2018. This interagency assessment, led by the Carbon Cycle Interagency Working Group (CCIWG) via the U.S. Carbon Cycle Science Program with Canadian and Mexican partners, also provides information on critical knowledge gaps and uncertainties related to terrestrial and aquatic carbon fluxes. Such information will guide future innovations, partnership needs, and scope out opportunities across public and private sectors. Examples of potential innovations include expanding GHG observations through commercial aircrafts to approach the frequency of existing temperature, pressure, and water vapor observations on those platforms, thus allowing for dramatic improvements in satellite retrievals and model results. Others include increased deployment of AirCore to get complete vertical profiles of GHGs, expanded monitoring and extension of existing model capabilities for coastal carbon budgets, and a substantial increase in observations of isotopologues of GHGs, which will substantially improve our ability to separate natural and human contributions.

Continuous atmospheric greenhouse gas measurements in a semi-remote area in the Kyrgyz Republic – first scientific findings towards policy making

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The availability of reliable scientific data to characterize the atmosphere's chemical composition is crucial for understanding climate change, its drivers, and its impacts. Despite a large number of measuring stations and considerable improvement in spatial coverage, there are, however, still regions of the world with very sparse observations monitoring atmospheric composition.

The project "Capacity Building and Twinning for Climate Observing Systems" (CATCOS) helps to close this gap by establishing and resuming systematic observations of greenhouse gases and other Essential Climate Variables in developing and emerging countries where the availability of observations is currently insufficient.

Within CATCOS, Empa established high-quality observations of carbon dioxide, methane, carbon monoxide, surface ozone and black carbon in the Kyrgyz Republic. Measurements started in August 2016 at the Cholpon Ata Lake Observatory operated by Kyrgyzhydromet. The observatory is located at the Northern shore of the Issyk Kul lake, a water surface of 180 times 60 km in size. To its north, a mountain range extends up to an altitude of 4300 m. In spring and autumn, when local activity in the region is low, the location provides ideal conditions to measure background greenhouse gas concentrations representative for a geographically large area. During summer, touristic activity is prevalent, leading to increased traffic and related emissions. In winter, residential heating with coal or wood in the nearby villages can occasionally lead to elevated greenhouse gas and particulate matter concentrations.

Thus, the station serves three main purposes: (i) the observation of representative background signals, (ii) the assessment of health relevant air quality, and (iii) the determination of the impact of local activities on air quality and greenhouse gas emissions in the rural Kyrgyz Republic. These aspects are key elements for linking science, inventories and policy in this rapidly developing but sparsely observed area.

Quantification of materially utilized carbon in our society: the case of Japan

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To achieve the goals of Paris Agreement, global society is directing much effort in substantially reducing greenhouse gas (GHG) emissions. In addition to energy-related efforts, prevention of carbon release into the atmosphere with carbon capture and storage (CCS) and/or utilization of biomass resources is considered indispensable to achieving the global objective. In this study, considering carbon-containing goods as carbon reservoirs in our society similar to forests and reservoirs enabling CCS, the flow of materially utilized carbon was quantified by input-output-based material flow analysis (IO-MFA). IO-MFA with high-resolution IO table such as Japanese IO table having over 400 sectors provides carbon contents for products of each sector. Based on the carbon contents of products analyzed by IO-MFA, in-use carbon annually retained in an economy is quantified and its in-use condition is also identified. As a result, in 2011, 6.3 Mt-C of petroleum-derived carbon and 7.9 Mt-C of wood-derived carbon were introduced to the Japanese society as end-use products (e.g., automobiles and constructions) in various forms (e.g., plastics and synthetic rubbers). The total amount (14.2 Mt-C) corresponded to 4.1% (52.1 Mt-CO2) of annual CO2 emission in Japan in 2011. Subsequently, by referring to the technology that can treat carbon in the target forms in end-of-life products, the recoverability of carbon as a material has been discussed with respect to each form and end-use of carbon. By numerically showing the necessity and potential of implementing appropriate technologies, this study provides scientific direction for policymakers to establish a quality carbon cycle in our society.

Posters for Session 6: Regional efforts to constrain the global C cycle

Air-sea CO_2 fluxes from pCO_2 continuous measurements in a coastal area: the role of atmospheric forcing under different wintry seasons

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While confidence in estimating air–sea CO_2 fluxes in open sea environments is increasing, a large uncertainty remains in defining the role played by coastal ecosystems as CO_2 sinks or sources. This is due to their highly variable oceanographic and climatic characteristics and to the effects of continental inputs.

Within ICOS-OTC network, the PALOMA station, (Northern Adriatic Sea), is continuously collecting sea surface pCO_2 data since 2012. In the framework of JERICO-NEXT project, PALOMA is working together with several stations located in European coastal seas to explore the role of biological and atmospheric drivers in determining the observed pCO_2 variability.

In this work, we present and discuss the effects of meteorological conditions on CO_2 air-sea fluxes, using the data collected in four wintry seasons from 2012 to 2016.

In winter 2012-2013, the presence of lower temperatures and the occurrence of several events of Bora (wind speed > 15 ms^{-1}) produced a decrease of the SST down to 8.3 C leading to more favorable conditions for CO_2 absorption. The following winter was characterized by a higher air temperature, weaker winds, intense precipitation and river discharges larger than the average of the previous decade. These distinct hydrological and meteorological conditions significantly affected the sea surface pCO_2 that was lower in 2012-2013 (median pCO_2 = 324 ± 8.9 µatm) than in 2013-2014 (median pCO_2 = 343 ± 9.0 µatm). Sea always absorbed CO_2 from the atmosphere, but average daily fluxes were almost doubled during the colder winter 2012-2013 (F = -6.4 mmol–CO_2 m^2d^{-1}) than in the milder winter 2013-2014 (F = -3.7 mmol–CO_2 m^2d^{-1}).

Our results highlight the sensitivity of the CO_2 sink in the northern Adriatic to changes in the meteorological conditions and suggest that its capability of sequestering CO_2 could dramatically decrease in the next decades under a climate change scenario.

Local situations identification in GHG atmospheric hourly time series using statistical methods vs atmospheric approaches

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Tall tower atmospheric stations are used within ICOS to understand the atmospheric GHG budget variations and to assess the surface fluxes at the regional scales. High quality atmospheric concentrations gradients are used in inversion system to provide estimation of the surface fluxes estimation. Hourly time series of the atmospheric concentrations exhibit strong variability from days to years time scale. These variations may be related to meteorological and climate changes and to sources and sinks variations. While these drivers at regional scales play a significant role, local meteorology as well as local sources and sinks may also contribute to the observed GHG concentrations variability. Within ICOS one of our aims is to study the regional signatures at scales that can be aproached by the model inversion and assimilation framework and by the statistical inventories of sources. It is therefore necessary to filter out situations where the local influence is dominant enough to shadow the regional signature.. Background on top of what the regional signal is added.also needs to be defined accurately. Such local situations and background definitions may be extracted from signal processing/time series analysis procedures and / or by using physical based approached .

El Yazidi et al. (2018) assessed the efficiency and robusteness of 3 statistical spikes detection methods for CO2 and CH4 and concluded that the SD and REBS methods could be used after parameters specification. Local situations or strong local influence may also be identified by atmospheric based fingerprints such as calm wind, strong thermal inversion, large fast CO2 /CH4 or CO variations large CO or NO2 signal. However some of these indices which can be correlated may also be related to larger scale signals.. We will present a comparison of the statistical and atmospheric based approaches and suggest the pros and the cons for each method.

A Representative Application of Future NPP Estimation by Combining Remote Sensing and Spatial Modelling

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Net Primary Productivity (NPP) is the amount of carbon uptake after subtracting Plant Respiration (RES) from Gross Primary Productivity (GPP) that measures the new plant growth. It is an important indicator for ecosystem performance that represents the overall trend of carbon cycle. Remote sensing and biogeochemical models have been combined in recent studies to estimate and evaluate the NPP potential in many regions, however, this is still an important research question for Turkey.

The objective of this study was to combine remote sensing and biogeochemical modelling to estimate the responses of Net Primary Productivity (NPP) to projected climatic changes in Turkey. Therefore, a multi-temporal data set including 16-day MODIS composites, land cover, soils and fractional percent tree cover data at a 250-m spatial resolution are integrated to the NASA-CASA biogeochemical approach. The future climate projections were based on the following Representative Concentration Pathways (RCPs) scenario defined in 5th Assessment Report of The Intergovernmental Panel on Climate Change: RCP 8.5.

The future NPP modeling was performed under CO_2 concentrations ranging from 421 to 936 ppm. Terrestrial NPP appeared to be sensitive to changes in temperature and precipitation. The model results provided promising results about a better understanding and quantification of ecological and economic implications of regional impacts of climate change on complex and heterogeneous landscape of Turkey.

Long-term socio-ecological carbon budget analyses enable tracing emissions shifts from land use to energy use

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Analyses of carbon budgets at regional scales have increased our understanding of the temporal dynamics and regional patterns of carbon sources and sinks. On the one hand, regional studies use a variety of different data sources, reducing data uncertainties prevalent at the global scale. On the other hand, they generated insights on regional trends, patterns and driving forces of carbon sources and sinks. However, few long-term studies exist at the regional scale, and little attention has been paid to the functional links between land-based carbon fluxes and socio-economic carbon emissions.

In this contribution, we argue that past ecosystem carbon sinks related to reforestation and afforestation have been causally linked to shifts in energy use, away from biomass towards the increasing use of modern, notably fossil energy. In particular, three processes contributed to relieving forests from pressure despite growth in population and affluence: (1) the substitution of fuelwood (2) agricultural intensification and (3) increased foreign trade of biomass. These processes in turn cause carbon and other greenhouse gas emissions which may compromise the forest carbon sink.

Based on the empirical example of Austria, we show that it is possible to quantify long-term shifts in carbon sources and sinks at the national scale during initial periods of national-level forest regrowth („forest transitions"). To this end, a variety of historical and recent statistical evidence, including forest inventories and agricultural statistics is combined. Furthermore, we display how a quantification of emissions from forest relief processes can be achieved based on the concept of socio-ecological metabolism, and discuss implications for climate change mitigation measures focusing on reforestation.

Net terrestrial ecosystem carbon fluxes in China during 2009 - 2015 constrained by both surface and satellite CO2 observations

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In this study, we use a global carbon assimilation system (GCAS) to infer the net terrestrial ecosystem carbon fluxes in China during 2009 – 2015. GCAS was constructed with the global atmospheric chemistry model MOZART4 and the local ensemble transform Kalman filter (LETKF). The system is improved with higher resolution of atmospheric transport model (global 1deg by 1deg), finer global zoning, capacity for the optimization of ocean flux and the assimilation of both surface and satellite (GOSAT) CO2 observations. Carbon exchanges with ocean from ocean inversion flux (OIF) and terrestrial ecosystem carbon exchanges simulated by BEPS are used as priori fluxes. Global annual uncertainties of 2.0 PgC/yr and 0.88 PgC/yr for bio and ocean fluxes are used, respectively. Fire emissions from GFED4, and fossil fuel carbon emissions from CDIAC, EDGAR and PKU-CO2 are adopted as fixed fluxes. In addition, in order to further improve the flux estimates in China, surface CO2 observations from four additional Chinese sites (i.e., Shangdianzi, Longfengshan, Linan and Shangri-La) are used, which are not included in the GlobalView CO2 package (obspack). Six experiments are conducted, namely 1) only surface observations (obspack, same thereafter) and with CDIAC emissions, 2) only satellite XCO2 and with CDIAC emissions, 3) both surface and satellite observations and with CDIAC emissions, 4) both surface, satellite and additional Chinese observations and CDIAC emissions, 5) using the same observations as 4) but with CDIAC emissions replaced by EDGAR emissions, 6) using the same observations as 4) but with CDIAC emissions replaced by PKU-CO2 emissions. Finally, the impacts of using GOSAT XCO2, four additional Chinese sites observations and different fossil fuel carbon emission datasets on the inverted net terrestrial carbon fluxes, the distribution of terrestrial carbon exchanges as well as their inter-annual variations in China are shown and discussed.

Evaluating year-to-year anomalies in tropical wetland methane emissions using satellite CH_4 observations

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Natural wetlands are the largest source of methane emissions, contributing 20–40% of global emissions and dominating the inter-annual variability. Large uncertainties remain on their variability and response to climate change.

This study uses atmospheric methane observations from the GOSAT satellite to evaluate methane wetland emission estimates. We assess how well simulations reproduce the observed methane inter-annual variability by evaluating the detrended seasonal cycle. The latitudinal means agree well but maximum differences in the tropics of 28.1–34.8 ppb suggest that all simulations fail to capture the extent of the tropical wetland seasonal cycle.

We focus further analysis on the major natural wetlands in South America: the seasonally flooded savannah of the Pantanal (Brazil) and Llanos de Moxos (Bolivia) regions; and the riverine wetlands formed by the Paraná River (Argentina). We see large discrepancies between simulation and observation over the Pantanal and Llanos de Moxos region in 2010, 2011 and 2014 and over the Paraná River region in 2010 and 2014. We find highly consistent behaviour between the time and location of these methane anomalies and the change in wetland extent, driven by precipitation related to El Niño Southern Oscillation activity.

We conclude that the inability of land surface models to increase wetland extent through overbank inundation is the primary cause of these observed discrepancies and can lead to under-estimation of methane fluxes by as much as 50% (5.3–11.8 Tg yr^{-1}) of the observed emissions for the combined Pantanal and Paraná regions. As the hydrology of these regions is heavily linked to ENSO variability, being able to reproduce changes in wetland behaviour is important for successfully predicting their methane emissions.

Systems analysis as a background to constrain regional carbon budget

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The diversity of estimates of regional carbon budgets is high. The carbon sink of terrestrial ecosystems of Russia was reported in peer-reviewed publications from ~150 to 800 Tg C yr-1 during the last two decades. Based on principles of the applied systems analysis we consider the ways, which would allow us to constrain the estimates following the methodology of a Full and Verified Carbon Account – FCA (Shvidenko et al. 2010, 2015). The major goal of the FCA is to get two equally important outputs: an unbiased proxy value (or distribution) and its uncertainty. However, the FCA is an underspecified (fuzzy) system. We discuss specifics of the accounting.

As an illustration we present the FCA for Russian forests. The landscape-ecosystem approach (LEA) serves an empirical and designing background of the FCA. Information basis of the LEA is presented by an Integrated Land Information System (ILIS), which contains (in a spatially and temporally explicit way) all available appropriate information about land, landscape, vegetation, soil, climate, disturbance etc. derived from diverse sources The ILIS is presented by a multi-layer GIS (the resolution is ~250 m). The detailed description of forests includes inter alia dominant tree species, age, average diameter and height, stocking, growing stock volume, live biomass by components, dead wood; data on major types of disturbances etc. The accounting scheme is based on a complimentary use of the stock-based and flux-based approaches and presents a “semi-empirical” estimate of the FCA. Other methods of carbon cycle studying (process-based models; eddy covariance; “direct” remote sensing assessments, like aboveground biomass or NPP; inverse modeling) are used for the mutual constrain of basic intermediate and final results) using the Bayesian approach. We discuss strengths and weaknesses of the methodology. Uncertainty of yearly NECB for large territories is estimated in limits of 25-30% (CI 0.9).

Model-data fusion framework to constrain Australia's terrestrial carbon and water budgets

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The Australian landscape is unique. It is characterised by large interannual variability in rainfall, and this drives significant variability in Australian carbon fluxes, particularly in semi-arid and savanna ecosystems. With its vast area, Australia also has significant carbon stocks. Here we constrain the CABLE terrestrial biogeochemical model for Australia at high spatial resolution (0.05^0, approx. 5 km) with multiple observation types: carbon and water fluxes at OzFlux flux sites, carbon pool data, litter fall, biometric data, remotely-sensed vegetation cover, soil moisture and streamflow data. These observations are used either to constrain model parameters in a model-data fusion framework or to compare with model simulations. We generate multiple parameter sets to allow exploration of the effect on model results of parameter equifinality (whereby multiple combinations of parameters can give an equally acceptable fit to the calibration data). Compared to the Australian contribution to RECCAP1, our model now contains a number of important enhancements, including demographic effects on biomass accumulation and turnover, and land-use and land-cover change, and is now constrained with additional observation types (biometric data and soil moisture).

Oral Presentations for Session 7: Reactive gases

Conveners: Christian Brümmer, Silvano Fares

Reactive gases are important for the chemistry of the atmosphere and lifetime of some GHG species. Ozone (O3) is itself a potent GHG, and is with carbon monoxide (CO) related to the removal of methane (CH4) from the atmosphere. Volatile organic compounds (VOCs) cover a wide range of molecules, and recent studies indicate that dimethyl sulfide (DMS) is connected to carbonyl sulfide (COS), a promising proxy of photosynthesis. Furthermore, ammonia (NH3) emissions from agricultural practices may act as a precursor for particulate matter, whereas atmospheric nitrogen deposition may have significant effects on the productivity of natural and semi-natural ecosystems. This session focuses on the reactive gases that either influence the concentrations or are related to the fluxes of CO2, CH4, or N2O.

Emissions of NO and N_2O from a pasture ecosystem measured by eddy covariance

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NO and N_2O are both emitted from ecosystems as an intermediate or byproduct of nitrification and denitrification processes in the soil. In managed agricultural ecosystems these emissions are enhanced by

nitrogen input through fertilization. While N_2O directly acts as greenhouse gas, NO is a reactive air pollutant that has effects on ozone formation but also on nitrogen input to (semi-) natural ecosystems leading to indirect N_2O emissions. Since the two gases have very different characteristics, their concentration and emission is usually measured by different techniques, and thus fully parallel measurements are rare. Previous measurements have commonly been performed with chamber methods, that have difficulties to determine average emissions under spatially heterogeneous conditions as met e.g. for pastures. We performed simultaneous emission flux measurements of NO and N_2O on a pasture field over an entire growing season using the eddy covariance (EC) method. Measured EC fluxes for NO may deviate from the soil NO emission due to fast chemical conversion to NO_2 (in the presence of ozone) below the measurement level. To investigate this effect, additional EC flux measurements for NO_2 were performed during selected periods.

For NO and N_2O mainly emission fluxes were observed for the managed pasture. For both gases, diurnal and seasonal cycles due to soil temperature were observed. In addition, emission levels strongly depended on management operations and soil moisture conditions. The results showed a clear difference in the optimum soil moisture conditions (high for N_2O, low for NO) for the emission of the two gases. Overall, the N_2O emission of the pasture was higher than the NO emission partly due to the frequently high soil water content. Unlike for cut grassland and crop fields, N_2O emission from the pasture was not limited to fertilizer events but occurred more continuously throughout the warm season.

Establishing nitrogen deposition over Germany using modelling and observations

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Introduction and methodology

This study uses the chemistry transport model LOTOS-EUROS in combination with wet deposition observations to calculate deposition of nitrogen, sulphur and base cations over Germany for the time period 2000-2015 at a 1x1 km resolution. This is the first time that such a long deposition time series has been calculated using a consistent methodology. For 2016, a special comparison was made with dry deposition measurements from the monitoring site in Forellenbach. Both aerodynamical, and stomatal resistances together with meteorological data are used to calculate exchange velocities. From observations at different heights, we retrieved measured exchange velocities. In general, the model underestimates for lower, and overestimates for higher exchange velocities.

Results and Conclusions

Nitrogen deposition over Germany on average declined from 1296 to 1058 Eq/ha/yr from 2000 to 2015, which is completely attributed to a reduction of oxidized N deposition. In the same period, S deposition declined from 385 to 188 Eq/ha/yr. While ecosystem damage due to acidification has declined significantly over the research period, eutrophication remains an issue because reducing ammonia emissions proves problematic.

Eutrophication of ecosystems remains a problem in Germany. The methodology presented here successfully combines wet deposition measurements with atmospheric modelling to come to a best estimate of total deposition. Trends in deposition can be investigated based on this work. While acid deposition has been strongly reduced over the past 15 years, deposition of (especially reduced) nitrogen has decreased much less. This emphasizes the need for further monitoring and emission reductions.

Acknowledgement
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Characterisation of ozone deposition to a mixed oak-hornbeam forest. Flux measurements at 5 levels above and inside the canopy and their interactions with nitric oxide

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In the framework of the FP7 project ECLAIRE a joint field campaign was conducted over a mixed oak-hornbeam forest in Marmirolo (MN), in the Po valley (I). The aim of this field campaign was to investigate the processes regulating the gas exchange between the forest and the atmosphere by investigating ozone fluxes and the interactions with other gases and atmospheric processes.

Measurements were made on a 40 m tower and sonic anemometers and fast ozone analyzers for eddy covariance were mounted at five different heights, two above canopy, one at canopy height and two below canopy. Eddy covariance fluxes of nitric oxide (NO) were measured above canopy and, together with NO2, at ground level with an automated dynamic chamber system.

Above canopy fluxes showed a good agreement with similar values (peaks around 10 nmol m-2 s-1). Surprisingly, in the morning the fluxes at 24 m (inside the canopy) were, on average, 3 nmol m-2 s-1 higher than those measured at 32 and 41 m. Two processes were involved in this flux enhancement at 24 m: NO fluxes converging at canopy level both from above and below canopy and the coupling/decoupling between the forest and the atmosphere. The former process led to the formation of an ozone sink at canopy level while the latter process allowed the 24 m flux enhancement only in the morning that is when the forest and the atmosphere were coupled.

An ozone flux partition will be presented too: most of the ozone, nearly 80%, was removed by the canopy following both stomatal and non-stomatal pathways and the ozone sink, due the reaction in gas phase tritation between NO and O3, removed 18% of the deposited ozone. Only 2% of the ozone was removed by deposition to the forest floor both on understory and soil.

Ozone deposition effects on carbon assimilation in a Mediterranean forest

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The ICOS network offers the opportunity to test the effects of toxic gas on carbon assimilation by crop and forest ecosystems. Tropospheric ozone is a powerful oxidant of particular concern for plants when it penetrates stomata and leads to oxidative stress. Damage to cells is often accompanied by early senescence and compromised stomatal functioning. Studying these dynamics in Mediterranean region is particularly relevant because of its climate characterised by high temperatures during the vegetative season and strong insolation that favour tropospheric ozone formation. Vegetation in this region has developed adaptations to the dry-hot summer conditions that could make them avoid or reduce the ozone stress. With the aim to verify if and how much ozone could affect the ecophysiological processes of the Mediterranean vegetation, we applied a multi-layer canopy model to a holm-hoak forest at Castelporziano, a natural reserve near the city of Rome (Italy) and ICOS candidate for level I site. We tested different models of stomatal conductance and different methods to assess ozone impact on stomatal aperture and Gross Primary Productivity. A suite of semi-empirical methods were parameterized with ecophysiological values measured at the leaf level, and the overall predictions were compared with continuous Eddy Covariance (EC) data. We analyzed which method could best work in a peculiar ecosystem such as the evergreen mediterranean forest. With this work we want to highlight the importance of integrating environmental monitoring and modelling for a deeper understanding of the complex mechanisms that affect forest ecosystems.

Ozone fluxes in the spruce forest at Bily Kriz, Czech Republic

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Forests as well as cities represent important sources of volatile organic compounds (VOCs) into the atmosphere. Hence, we present fluxes of various VOCs measured above Norway spruce forest at Bílý Kříž experimental station (Beskydy Mts., NE of the Czech Republic) by PTR-TOF-MS 8000 (Ionicon Analytik, Austria) and above the city of Innsbruck (Tirol, Austria) measured by PTR-qTOF-MS (operated in both H3O+ and NO+ mode) coupled with eddy covariance technique. In particular, diurnal courses of benzene and toluene fluxes will be shown in relation to an intensity of city traffic and spruce stomata behaviour, respectively. Diurnal courses of biogenic VOC emissions, dominated by monoterpenes and isoprene in forest ecosystem and isoprene and 2-methylbut-3-en-2-ol in urban environment, will be also presented. Moreover, fluxes of tropospheric ozone measured by fast chemiluminescence sensors coupled with eddy covariance show net emission from city of Innsbruck and net deposition into the forest ecosystem. We will discuss the link between sources and sinks of various VOCs and ozone represented by city of Innsbruck and Norway spruce forest, respectively.

Posters for Session 7: Reactive gases

Reactive nitrogen exchange between biosphere and atmosphere – lessons learned from applying novel measurement techniques during NITROSPHERE and FORESTFLUX campaigns

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Field campaigns were carried out to investigate biosphere-atmosphere exchange of reactive nitrogen compounds with the aim to test novel measurement techniques in eddy-covariance setups for continuous determination of ammonia and total reactive nitrogen fluxes. While high-frequency concentrations of ammonia were measured with a quantum cascade laser absorption spectrometer, a custom-built converter coupled to a chemiluminescence detector was used for the determination of total reactive nitrogen. Campaigns were conducted above cropland, forest and peatland ecosystems. Substantial high-frequency damping on fluxes in the range of 15-35% was observed. Damping was found to be dependent on land use and its specific setup, but appeared to be mainly invariant with wind speed and atmospheric stability. Nitrogen fluxes showed strong diurnal variability after fertilization on arable land with peak emission during midday. Moderate diurnal variability with highest uptake around noon was found at a forest site located in a national park. Exchange patterns were mainly controlled by concentration and to a lesser extent by light, vapour pressure deficit, and surface wetness depending on season and land use. An analysis of multidimensional functional relationships with artificial neural networks showed that up to 50% of the variability in nitrogen fluxes could be explained when the three most dominating factors were used. While measured data and results from a state-of-the-art inferential exchange scheme compared fairly well, a combination of the two approaches could be used for determining seasonal nitrogen budgets for natural and semi-natural sites. The results help improve our knowledge of the temporal variability of surface-atmosphere exchange over different ecosystems, thereby providing useful validation opportunities for inferential models. It is highly desired to complement standard ICOS long-term observations of greenhouse gases – at least at some selected key sites – with high-frequency reactive nitrogen measurements to strengthen process understanding of coupled nitrogen and carbon cycles.

Evaluation of gap-filling strategies for ammonia flux measurements

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With recent technological advances, micrometeorological flux measurements of ammonia have become available over a variety of ecosystems. Since these measurements are not valid under certain conditions

such as low turbulence and reactive species additionally reveal a low signal-to-noise ratio, the number of gaps is usually even higher than for other typical greenhouse gas measurements such as carbon dioxide. Furthermore, the knowledge about the various interactions of biophysical factors and management driving the ammonia exchange is still highly uncertain.

To develop suitable gap-filling schemes for ammonia fluxes, we used data from three campaigns of semi-natural ecosystems. The half-hourly data was also averaged to three-hourly and daily time step which may reduce the noise in the data. The main driving factors were characterized using an inductive approach based on artificial neural networks. These results were used to optimize the different gap-filling methods, i.e. mean diurnal variation, look up tables, and artificial neural networks. Additionally, we applied an inferential model parameterized to the local conditions to fill the gaps. All four methods were tested for different artificial gap scenarios to evaluate their performance and to get an estimate of the uncertainty induced by gap-filling. Establishing common gap-filling strategies will help to improve the robustness of ammonia emission estimates.

Emissions of biogenic volatile organic compounds from boreal peatlands

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Biogenic volatile organic compounds (BVOC) emissions have generally been connected to vegetation composition, but so far the link in peatlands is weakly established. This study aims to describe what kinds of BVOCs are emitted and to quantify the rate of BVOC emissions as controlled by peatland type and vegetation composition in Siikaneva peatland complex in southern Finland (61°50’N, 24°12’E). To study the role of Sphagnum mosses and vascular plants, root exclusion technique is used to segregate the BVOC emissions from bare peat, mosses and vascular plants. Emissions from both the fen and the bog sites of Siikaneva are measured with static chamber technique during the growing seasons 2017 and 2018 and analyzed with gas chromatograph.

Budget of ammonium in the Southern Ocean: implication for the interpretation of ammonium ice core data

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It has been suggested that the concentration of ammonium in Antarctic ice cores is related to the productivity of the Southern Ocean, an important control on atmospheric CO2. However this link has not been firmly established, in part because of large uncertainties in seawater ammonium and its outgassing.

To address this question, we introduce an interactive representation of the exchange of reactive nitrogen between atmosphere and ocean in the GFDL Earth System model.

Here. I will discuss the sensitivity of the ocean source of ammonia to variability in ocean productivity (including through dust deposition), sea surface temperature and pH, with an emphasis on the Southern Ocean

I will also discuss the relative contribution of ocean, fire, soil and aviary sources of ammonia to ammonium deposition in Antarctica and its implication for the interpretation of ammonium ice core records.

Coupled biosphere-atmosphere exchange modelling of NH_3 and CO_2

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Biosphere-atmosphere exchange of trace gases is commonly modelled using semi-empirical resistance analogies, both on the plot-scale and within spatially explicit applications. These models are nowadays able to infer dry deposition fluxes with reasonable accuracy using standard meteorological variables and measured or modelled concentrations only. However, they are not only valuable as a predictive tool in the absence of direct flux measurements, but also as a means to analyse, interpret, and quality-check data from micrometeorological stations.

Currently, these models usually operate on a per-species basis, with little to no chemical and/or physiological interactions between the compounds of interest. Stomatal controls are often modelled empirically with average ecosystem-specific parameterisations, or using H_2O-flux based estimates. These approaches suffer from a number of uncertainties, e.g. due to nontrivial partitioning of evapotranspiration, and they are often unable to capture the effects of increasing CO_2 concentrations on stomatal conductance, limiting their applicability in climate change studies.

In this contribution we demonstrate the value of extending an NH_3 biosphere-atmosphere exchange scheme with a simultaneously computed pathway for CO_2 exchange, and linking the two at the stomatal pathway with the Ball-Berry stomatal conductance model. We discuss results from two exemplary applications of the coupled approach: (a) deriving stomatal conductance from measured CO_2 fluxes to aid the interpretation of measured NH_3 fluxes, and (b) modelling CO_2 fluxes to validate the stomatal pathway of an NH_3 exchange model and using it for predictive modelling of NH_3 fluxes. Preliminary results suggest that coupled modelling of NH_3 and CO_2 exchange can reveal otherwise hidden processes in a model-based flux data analysis. It also allows for a straightforward, valid, and site-specific parameterisation of the stomatal pathway, indicating a potential for retrofitting existing flux towers with low-cost NH_3 samplers to provide more trustworthy estimates of NH_3 dry deposition than with default parameterisations.

An eddy covariance system for simultaneous flux measurements of total reactive nitrogen, ammonia, and nitrogen oxides (NOx)

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Atmospheric reactive nitrogen exists in many forms, from highly oxidized species such as nitric acid (HNO_3), nitrogen dioxide (NO_2), and nitrate (NO_3^-), to highly reduced forms such as ammonia (NH_3), ammonium (NH_4+) and organic amines. These species are important to various chemical processes including ozone production, acidification of rain, particle formation and growth, and nitrogen deposition to soil and water. Reactive nitrogen deposition from gas and particle phases has a direct impact on soil health, affecting agricultural productivity and sensitive ecological balances.

We present our research to develop a measurement system to quantify the deposition and emission of reactive nitrogen species at soil surfaces. This system incorporates a dual inlet sampling system with an Aerodyne tunable infrared laser direct absorption spectrometer (TILDAS). The instrument measures total reactive nitrogen, Nr (all N compounds except N_2 and N_2O), via one inlet, and its two largest components, ammonia and nitrogen oxides (NOx), via the second inlet.

The total reactive nitrogen measurement involves thermal and chemical conversion of all gas and particulate nitrogen species to nitric oxide (NO) -- the thermal conversion of nitrogen species to NO and NO_2, followed by the catalytic conversion of NO_2 to NO. We have demonstrated a conversion efficiency of >99% and a time response of ~0.4 sec. Ammonia and NOx are detected via an Aerodyne inertial inlet to achieve fast time response of NH_3. The inlet is doped with ozone to convert NO to NO_2 for a total NOx measurement.

The resulting system combines the flows of the Nr converter and the inertial inlet to pass through the dual laser TILDAS configured to quantify NO, NO_2, and NH_3. Simultaneous high precision, fast response detection of NO, NO_2 and NH_3 has been demonstrated

Oral Presentations for Session 8: Newest new in research – scientific and technical developments

Convener: Timo Vesala

This session gives space to innovative approaches and pioneering efforts in integrative biogeochemical studies. The session is open for any type of approaches and research objects which are still scarce. Few examples are in-situ measurements including vertical profile retrievals of CH4 from the ground-based total carbon column observing network (TCCON), atmospheric measurements on the voluntary observing ships (VOS) platforms, unmanned aerial vehicles (UAV) for concentration or vegetation monitoring, inland water carbon cycle observations and indirect estimation of photosynthesis (like in-situ reflectance/fluorescence and carbonyl sulphide uptake).

When soil water is not enough: using electric resistivity tomography as a proxy for the total water available to ecosystems

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Mediterranean ecosystems experience yearly summer droughts which intensity increases with climate change. There, the water holding capacity is therefore paramount for plant survival. Yet most Mediterranean forests grow on shallow, heterogeneous soils on top of a fragmented bedrock. Trees actually transpire more water during the summer than that can be stored in the shallow soil. Methods recommended in ICOS focus on soil, and therefore monitor only partially the total water resource.

We investigated the potential of electrical resistivity tomography (ERT) as an indicator of the water resource down to several meters (including soil plus rock), and its spatial variability. ERT results in the imaging of the underground electrical resistivity along a linear transect where electrodes are implanted for electrical current injection. Resistivity is influenced by material type, water content, solute content, and temperature. We assumed that the percentage variation in resistivity (PVR) between measurements made at two dates, one during a very wet period and one during a very dry period, was mainly influenced by changes in water content.

We set up transects at the Font-Blanche and Puechabon ICOS sites, in southern France, and compared PVR with independent measurements of soil and subsoil water contents, tree water potentials, and leaf area index (LAI).

We found a positive correlation between PVR and variations in water content measured with a neutron probe down to 4 meters, suggesting PVR could be a good proxy for estimating water holding capacity. We also found that trees with the lowest water potentials were growing in areas with lowest PVR (i.e. less water holding capacity). Similarly, LAI was also linked to PVR. Those results from two different ICOS sites using both physical, as well as biological data, suggest that ERT has the potential to describe the water resource for deep rooted forests growing on heterogeneous rocky substrate.

COS as a GPP proxy: Five years of COS flux measurements over a boreal forest

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Carbonyl sulfide (COS) is the most abundant sulfur compound in the atmosphere, with global average tropospheric mixing ratio around 500 ppt. COS has been suggested to be a useful proxy for photosynthesis (described by gross primary production, GPP) as it shares the same pathway with carbon dioxide (CO_2) in the leaf stomata but, in contrast to CO_2, is not respired back to the atmosphere. Traditionally GPP is defined from ecosystem scale measurements of CO_2 flux taking into account respiration defined from the night-time CO_2 flux data. During recent years, ecosystem scale studies of COS have increased in number, yet only one multi-year study has been published over a temperate forest. In this study we measured COS and CO_2 exchange over a boreal forest in Finland using eddy covariance (EC) technique during years 2013-2017, complemented by two years of soil and branch chamber measurements. GPP is defined from both the traditional method and direct COS flux measurements, taking into account radiation dependency in leaf relative uptake (LRU) ratio, that defines the leaf-scale normalized ratio of COS to CO_2 assimilation rates. Flux measurements are examined together with different environmental factors - such as temperature, moisture and radiation - to find the most significant COS flux drivers and possible differences with the two GPP methods, as well as deficiencies in COS as a proxy for photosynthesis. To our knowledge, this is the first multi-year study on ecosystem scale COS exchange over a boreal forest, even though the boreal region covers 30 % of the Earth's total forest area.

The Flying Tree Top Sampler - Sampling foliage from the uppermost canopy of trees using a drone

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Tree researchers around the globe are highly dependent on foliage and twig samples to gain insight in trees' ecophysiology. Various techniques have been established to access the canopies of a wide range of trees at different heights, e.g. canopy cranes, forklifts, tree climbers or shotguns. However, these techniques suffer from a great disadvantage: they are incapable of reaching the very top of the canopy (except canopy cranes). Here, we present a novel technique to sample the uppermost foliage and twigs from trees using a drone, the Flying Tree Top Sampler (FTTS). The tree top canopy is most exposed to environmental conditions such as solar radiation, wind or precipitation, and dominates any remote sensing scene. Foliage reacts within minutes to changing environmental conditions, hence it is important to quickly analyse samples after cutting, e.g. for chlorophyll content, fluorescence, light response curves of photosynthesis, or stomatal conductance. With the FTTS, the sample is delivered in less than a minute once it is cut. Due to its short sampling time (< 3 min / sample), the FTTS is capable of sampling a large number of trees within a short time period. Our approach is cost efficient and hardly dependent on infrastructure, although a permit might be necessary. Another key issue is the calibration of spectral proxies remotely sensed from satellites, aircrafts or drones. Sampling with the FTTS can easily be synchronized with overflights. The FTTS consists of a commercial drone equipped with a novel sampling mechanism, which automatically detects a twig within reach, grasps it and guides it over a circular saw blade to be cut. The sample can be released on demand without landing the drone making the FTTS immediately ready for the next sampling. We have successfully tested the FTTS on broadleaf and conifer trees.

^{222}Rn as tracer for quantifying greenhouse gases fluxes: need of high quality and harmonized measurements of atmospheric concentrations and fluxes.

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In order to estimate GHGs emissions, bottom-up and top-down methods are widely applied and the scientific community is focusing on reducing their related uncertainties. Techniques such as the Radon Tracer Method (RTM) have contributed to studies leading to improvements of these previous methods. In the RTM the atmospheric concentrations and the fluxes of the natural radioactive noble gas radon (^{222}Rn) are used to retrieve GHGs fluxes. The use of ^{222}Rn as tracer for GHG studies increases the need to monitoring its atmospheric concentrations with high spatial density and to produce reliable radon flux inventories. Networks of atmospheric stations, such as ICOS and ClimaDat, already started to perform atmospheric ^{222}Rn measurements. A harmonization of these data is needed. National and international scientific groups are currently working to: i) improve measurement techniques of atmospheric ^{222}Rn concentrations; ii) build robust and user friendly atmospheric radon monitors; iii) enlarge the atmospheric ^{222}Rn measurements network in Spain and to work towards harmonization across Europe; iv) improve continuous radon flux measurements; iv) achieve a standardization of the RTM for the retrieval of GHGs fluxes in rural and urban areas. Here, we will present the research we are carrying out in this field in relation to the previous research topics and recent advances achieved thanks to new shared projects.

Simultaneous measurement of δ13C-CO2, δ18O-CO2 and δ17O-CO2 in atmospheric samples by the Aerodyne Quantum Cascade Dual-Laser Absorption Spectrometer at the Centre for Isotope Research

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Absorption spectroscopy in the near infrared, using quantum cascade lasers, has proved to be a solid method for measuring δ13C-CO2 and δ18O-CO2 directly on atmospheric samples. We present results from a new Aerodyne dual-laser spectrometer system (SICAS) capable of simultaneously measuring δ13C-CO2, δ18O-CO2 and δ17O-CO2. The measurement of δ17O-CO2 next to δ18O-CO2 allows for the determination Δ17O-CO2 (Δ17O = ln(δ17O +1)-0.528×ln(δ18O +1)), an important parameter to study gross primary production (1).

So far, measurement of δ17O on atmospheric CO2 has been problematic due to the contribution of both 13C and 17O substituted CO2 to the mass 45 beam, detected by IRMS systems. Measuring δ17O-CO2 by mass spectrometry is only possible by conversion of CO2 to O2 (2) or detection of CO2 fragments. As absorption spectroscopy detects abundancies of single isotopologues, δ17O-CO2 can be meaured directly without the need for CO2 extraction or other sample preparation. We present δ13C-CO2, δ18O-CO2, δ17O-CO2 and Δ17O-CO2 in air samples from 4 different sites, being Lutjewad monitoring station in the Netherlands, the F3 oil platform in the North Sea, the coastal station Mace Head in Ireland, and Halley Bay station in Antarctica. These sites cover different climate zones and provide a mix of marine and terrestrial signals giving insight in the global distribution of Δ17O-CO2. The SICAS is calibrated using a suit of working standards linked to the VPDB scale for δ13C-CO2 and δ18O-CO2. Calibration of δ17O-CO2 is still work in progress. We have tried to combine determination by dual inlet IRMS at the IMAU, with determination based on CO2 in isotopic equilibrium with VSMOW-2 water at CIO.

1. Hoag, KJ, Still CJ, Fung IY, Boering KA, Geophys. Res. Lett., 2005; 32: L02802
2. Mrozek DJ, van der Veen C, Kliphuis M, Kaiser J, Wiegel AA, Röckmann T, Atmos. Meas. Tech. 2015; 8: 811

Posters for Session 8: Newest new in research – scientific and technical developments

Investigating the limitations of frequency response correction methods for eddy covariance fluxes with low signal-to-noise ratio

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Turbulent fluxes measured by eddy covariance technique (EC) are subject to high frequency losses due to physical limitations in instrument response times, separation of instruments, line averaging and air transport through the sampling tubes. For closed-path systems, the low-pass filter transfer function is often empirically estimated from either the measured power-spectra (PS) or co-spectra (CS) of sonic temperature and the target gas mixing ratio.

EC fluxes with low signal-to-noise ratio are typically found in many ecosystems for methane (CH_4) and nitrous oxide (N_2O). It is often assumed that the noise does not affect CS because it does not correlate with the vertical wind velocity, making attractive the use of CS in the estimation of the frequency cut-off. On the other hand, the use of CS relies on the correct determination of the lag time, which may be difficult in case of low fluxes. Alternatively, by using PS for the low-pass filter transfer function estimation, the high frequency noise must be removed from the spectra and the flux correction due to the sensor separation effect must be added to the processing algorithm.

In this study, we examine the effects of the signal to noise ratio on the uncertainty in the estimation of the spectral low-pass filter transfer function with either based on PS or on CS. We use differently low-pass filtered temperature time series to which white noise is systematically added. The results are then interpreted in with respect to the choice of the optimal method for the spectral correction of CH_4 and N_2O fluxes. The findings are relevant for defining a standard procedure for the post-processing of non-CO_2 greenhouse gas fluxes in flux observation networks such as, i.e., ICOS.

High-resolution inverse modelling of CH_4 emissions around monitoring station Ispra, Italy - first results

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High spatial resolution of atmospheric transport models is essential to improve the model representation of regional atmospheric monitoring stations and to improve regional greenhouse gas emission estimates. We present a novel four-dimensional variational (4DVAR) inverse modelling system based on the Lagrangian particle dispersion model FLEXPART, driven by meteorological fields from the COSMO-7 numerical weather prediction system at a horizontal resolution of 7 km. The regional FLEXPART / COSMO inversion system is coupled to the global / European TM5-4DVAR inverse modelling system, providing the boundary conditions (background CH_4 mole fractions).

The coupled system has been applied to estimate the regional CH_4 emissions around the monitoring station Ispra, Italy in 2011. Here, we present first results, including sensitivity experiments investigating the impact of different a priori emission inventories, assumed model representation errors and further parameters on the derived emission estimates. Furthermore, we compare the results from the 4DVAR inverse modelling system with an Extended Kalman filter system.

Initial characterisation of low-cost GHG sensors

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The purpose of the TRACE project is to develop new technologies to measure greenhouse gas (GHG) emissions with high accuracy and precision, at length scales ranging from an industrial site or a city up to national and global GHG budgets. For local GHG sources, the project is developing arrays of low-cost in-situ sensors based on current prototypes, which will be used to monitor mainly CH4 emitting sites including landfill and industrial sites. For country and global budgets measurements, a GHG-measuring satellite platform based on passive infrared spectrometers is being developed to provide global coverage with a resolution of a few kilometres. Emission maps derived from satellite measurements will be created using atmospheric data transport assimilation and inverse modelling. The research is being undertaken with three industrial partners, with the aim of building closer links between industry and academia, and developing commercial products and services.

This presentation focuses on the development and characterisation of the low-cost CO2 and CH4 dataloggers. CO2 measurements are based on a prototype NDIR-based instrument, while CH4 measurements are made using commercially available metal-oxide semiconductor sensors, including the Figaro TGS 2600. Here we present investigations into long-term drift, accuracy and precision, following long comparison runs against reference gas analysers. Data from these long runs will be used to correct for the ongoing effects of sensor drift, with the aim of providing high-quality data over a range covering normal atmospheric concentrations and industrial emissions.

CloudRoots – an integrated measurement and modelling approach for soil-plant-atmosphere interactions applied to an ICOS site

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Due to their high-quality routine measurement programme, ICOS sites lend themselves as anchors for additional experiments. As an example, we describe the CloudRoots campaign near the agricultural site Selhausen (DE-RuS) in spring 2018.

Little is known about the two-way feedback between stomatal control (controlling the partitioning of energy into sensible and latent heat) and cloud development (affecting potential evapotranspiration). Coupled models of the soil-vegetation-boundary layer continuum have the potential to explain this, but their calculations are only as robust as the data used to parameterize or validate the model. For observations and modelling, the challenge is in interconnecting processes at leaf level to the physics of turbulence and clouds.

We temporarily amend the existing radiation, flux and soil dynamics/respiration measurements of the ICOS site by scintillometry, sap-flow and leaf-level flux measurements, vertical profiles and isotope measurements. Scintillometers provide minute-scale turbulent fluxes enabling to connect stomatal responses to the energy, moisture and CO_2 fluxes at this timescale [1]. Sap-flow [2], leaf-level chamber, canopy-resolving profile [3] and isotope measurements have the potential to distinguish stomatal CO_2 and H_2O fluxes from the eddy-covariance based net fluxes. Relating the leaf and canopy level measurements to cloud development and potential cross-scale feedbacks are integrated and explored with the CLASS model ([4], https://classmodel.github.io).

The campaign is partnering with two complementary test campaigns for the FLEX mission (https://earth.esa.int/web/guest/missions/esa-future-missions/flex) and the MOSES project (https://moses.eskp.de/home/), taking place, among others, in the same region in spring and summer 2018. The poster will show first results and method intercomparisons from the CloudRoots field campaign.

[1] van Kesteren et al. 2013, Agric. For. Meteorol. 178-179:75-105
[2] Langensiepen et al. 2014, Agric. For. Meteorol. 186:34
[3] Ney and Graf 2018, Bound.-Layer Meteorol. 166:449
[4] Vilà-Guerau de Arellano et al. 2015, Atmospheric Boundary Layer: Integrating air chemistry and land interactions. Cambridge University Press.

Integration of a new ICOS compliant soil chamber with a five species Cavity Ring-Down Spectrometer for soil flux measurements

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Investigations of greenhouse gas exchange fluxes between the soil and atmosphere are crucial for gaining a better understanding of soil microbial processes. N_2O is of particular interest because soils can either be a source or sink of N_2O, and therefore, the overall effect of soils on the nitrogen cycle is difficult to quantify. Investigations of the nitrogen cycle were enormously facilitated due to the advent of Cavity Ring-Down Spectrometers because they allow real time measurements of N_2O in combination with other greenhouse gas species.

The Picarro G2508 greenhouse gas analyzer is a Cavity Ring-Down Spectrometer that allows continuous measurement of the three most important anthropogenic greenhouse gases, CO_2, CH_4 and N_2O together with NH_3 and H_2O. As such, the analyzer has proven to be an excellent tool to study soil fluxes.

Here, we present the integration of a new ICOS compliant, recirculating soil chamber from Eosense with the Picarro G2508 greenhouse gas analyzer for soil flux studies.

Improved eddy fluxes with Multi-Path sonic anemometry

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Bias of eddy covariance fluxes caused by sensor-induced flow distortions is a topic of on-going discussions since sonic anemometers-thermometers are used in I

COS. Until now there was no sensor head geometry that meets all simultaneous requests, as wide acceptance angle, low bias of the vertical wind component (the primary variable for eddy covariance application) and insensitivity with respect to precipitation. A common feature of traditional design of 3D-sonic anemometers is the use of three pairs of sound transducers that span three non-coplanar measuring paths. We show that the requests are no longer contradictory, if the rigid scheme of transducer pairs is dropped in favor of communicating transducer groups. Such Multi-Path concept offers the possibility of measuring the vertical wind component using vertical paths with a high degree of redundancy, improved accuracy, reliability and automatic failure detection procedures. The main aspects of head geometry, signal processing and expected advantages will be discussed. The Multi-Path concept allows to simulate traditional head geometries with tilted paths and to compare the results with fluxes obtained by vertical paths. First field trials confirm that there is a geometry-related bias, which has been reported in several recent studies, and which is apparently avoided by using vertical paths for the vertical wind component.

Characterisation of tall tower source areas using concentration footprints for periods of typical air flow regime

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For the correct interpretation of CO_2 concentrations measured at tall towers it is essential to know likely source area. The basic way how to estimate it is to calculate the tall tower concentration footprint. To get more general information about source area it is possible to combine more individual footprints from longer period. This study deals with the question how footprints are connected with the wind characteristics measured at the point of receptor (tall tower).

The concentration footprints of tall tower Křešín (which is part of National Atmospheric Observatory Košetice in central Czech Republic) for period 2006-2014 was calculated using particle dispersion model STILT - Stochastic Time-Inverted Lagrangian Transport model (Lin et al., 2003). We looked for general characteristic - the average footprint, for each season of the year from this set of individual footprints. For the reason to find also typical footprint (without need to calculate as much individual footprints as in the case of average footprints) we applied statistical analysis on wind speed and wind direction data from reanalysis ERA interim to find out typical air flow regime at the point of the receptor. Thanks to this the calculation of typical footprint for shorter period was possible. Comparison of typical and average footprint was performed to get information how much they respond to each other.

This estimation of typical footprints on the basis of air flow analysis can be useful because calculation of average footprints for longer period is time consuming and computationally demanding.

Lin. J.C., et al., 2003: A near-field tool for simulating the upstream influence of atmospheric observations: The Stochastic Time-Inverted Lagrangian Transport (STILT) model. J. of Geophys. Res., 108(D16), 4493

Versatile Glider, Atmospheric and Ship pCO2 Analyser - VeGAS-pCO2 - A Novel compact and high precision pCO2 sensor for Terrestrial and Ocean Observatories

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The success of regional and global CO2 observational networks to derive low-uncertainty CO2 flux assessments depends critically on the sustained and traceable quality of observations. Moreover, it is important that these criteria are met across multiple platforms, particularly emerging autonomous systems. We present a new approach towards a versatile high precision pCO2 analyser that fulfils the requirements of sustained data quality for ocean, atmospheric and terrestrial applications of long-term observations of CO2. The instrument, based on the well-established NDIR sensor, was initially developed for 3 – 12-month deployments of gliders in the Southern Ocean. We present the results of a 10-week test deployment in 2017- 2018 that emphasizes its capacity to deliver quality data under extreme conditions with a < 3% loss of data and precisions of < 0.2µatm in the lab and < 2µatm in the field. Two additional derivatives of the same versatile sensor architecture have been developed. A ship-based application that is designed to have a comparable autonomy and a precision of < 2µatm in the ocean and < 0.2µatm for the atmospheric sampling. A terrestrial / atmospheric version, which was tested against a CRDS instrument at Cape Point GAW station, South Africa and produced a mean bias of 0.0075µatm and a mean precision of 0.11µatm for re-sampling of span gas over 3 weeks. We think that preliminary accuracy and precision data can be improved, particularly for the autonomous ocean platforms. This will provide these sensors with the required attributed of robustness, long autonomy and high precision for global and regional integrated carbon observatories.

Developing a $^{14}CO_2$ sampling system and strategy to verify fossil fuel emissions from Rotterdam area, the Netherlands.

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As part of the ICOS RINGO project Task 1.2, my project aims to verify the fossil fuel emissions from the Rotterdam area. This is achievable via an upwind-downwind scheme, in which atmospheric sampling and measuring systems are installed at two stations, situated “before” and “after” the Rotterdam area in terms of wind direction. The locations of the upwind and downwind stations chosen for my project are the 2e Maasvlakte area and Cabauw atmospheric station, respectively. They are chosen so that when the wind comes from the west, the upwind station would get “clean” signals from the sea, while the downwind station would see the contamination as the air mass moves through the Rotterdam industrial and residential area. The project consists of 2 phases. In the first phase (started in January 2018), a Picarro G2301 CRDS analyser is placed in the 2e Maasvlakte to monitor the atmospheric conditions of the area over the following months. For Cabauw, long-term measurements have already been made up on the tall tower. Comparing the measurements made at the two sites between January and March 2018, along with the meteorological data taken from a KNMI weather station (at Hoek van Holland), it can be seen that when the wind is coming from the west, the Cabauw station picks up higher CO_2 signals and when the wind is coming from the east, the 2e Maasvlakte station picks up higher CO_2 signal (of up to around 5-10ppm). This information confirms the initial theories and helps to develop a suitable sampling strategy for phase two. In phase two (in development), two automated atmospheric flask sampling systems are to be built and tested, and deployed to the two stations to collect air samples for $^{14}CO_2$ analysis being made later on, to quantitatively determine the fossil fuel signals from Rotterdam.

Novel method of extraction for atmospheric $^{14}CO_2$ samples for determination of CO_2 emissions from fossil fuel

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The radiocarbon (^{14}C) content of atmospheric carbon dioxide (CO_2) has interested atmospheric researchers as a method to quantify recent CO_2 emissions from fossil fuels in the atmosphere. Now that decades have

passed since the Partial Nuclear Test Ban Treaty and the peak in $\Delta^{14}CO_2$, fossil fuels are the main influence on the long-term trend of $\Delta^{14}CO_2$.

The effect on $\Delta^{14}CO_2$ to local additions of fossil fuel-derived CO_2 depends on the concentration of the atmospheric CO_2 and fossil carbon (-1,000 ‰). Not considering other effects from the carbon cycle, the influence of $\Delta^{14}CO_2$ to fossil fuel-derived CO_2 is approximated by (-1,000 ‰ - $\Delta^{14}CO_2$)/CO_2. This is presently -2.6 ‰ ppm^{-1} but with predictions from climate models, this is likely to drop to - 1.6 ‰ ppm^{-1} by 2050, - 0.8 ‰ ppm^{-1} by 2100 (Graven, 2015).This suggests that measurement precision, currently ~ 2 ‰, will have to increase by a factor of 2 in the next decade.

To improve the precision of the measurement a novel extraction method, with a reduction in the number of steps, has been established. Following the development of the of the Automated Graphitisation Equipment (AGE III) (Wacker et al., 2010), we have developed an attachment system for whole air glass flasks. The manual system directly traps CO_2 from a whole air glass flask sample onto a molecular sieve (zeolite, 13X) trap, part of the AGEIII system. The results from this will be presented.

Graven, H. D.: Impact of fossil fuel emissions on atmospheric radiocarbon and various applications of radiocarbon over this century, Proc. Natl. Acad. Sci., 112(31), 9542–9545, doi:10.1073/pnas.1504467112, 2015.

Wacker, L., Němec, M. and Bourquin, J.: A revolutionary graphitisation system: Fully automated, compact and simple, Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms, 268(7–8), 931–934, doi:10.1016/j.nimb.2009.10.067, 2010.

Outcomes of the ongoing improvement work to develop and increase the Readiness of ICOS for Necessities of Integrated Global Observations

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ICOS is improved in a 4-year H2020 project called RINGO (Readiness of ICOS for Necessities of Integrated Global Observations). Ringo has 43 partners in 19 countries and consists of 5 work packages with specific emphasis on the further development of the readiness of ICOS Research Infrastructure (ICOS RI) to foster its sustainability.

RINGO's five principal objectives are:

1. Scientific readiness: To support the further consolidation of the observational networks and enhance their quality. This objective is mainly science-guided and will increase the readiness of ICOS RI to be the European pillar in a global observation system on greenhouse gases.

2. Geographical readiness: To enhance ICOS membership and sustainability by supporting countries to build a national consortium, to promote ICOS towards the national stakeholders, to receive consultancy e.g. on possibilities to use EU structural fund to build the infrastructure for ICOS observations and also to receive training to improve the readiness of the scientists to work inside ICOS.

3. Technological readiness: To further develop and standardize technologies for greenhouse gas observations necessary to foster new knowledge demands and to account for and contribute to technological advances.

4. Data readiness: To improve data streams towards different user groups, adapting to the developing and dynamic (web) standards.

5. Political and administrative readiness: To deepen the global cooperation of observational infrastructures and with that the common societal impact. Impact is expected on the further development and sustainability of ICOS via scientific, technical and managerial progress and by deepening the integration into global observation and data integration systems.

RINGO will reach its' mid-term review one week prior this Conference and these received results will be presented and opened for discussion among the entire community with this poster.

From Measurements to Analysis: New Tools for Time- and Space-Synchronized Flux and Optical Sensor Network

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Many presently operating flux stations have weather and soil data to help clean, analyze and interpret the fluxes. However, most of them do not have optical proximal sensor measurements, do not allow straightforward coupling with remote sensing data, and cannot be easily used for validation of remotely sensed products, ecosystem modeling, or upscaling from the field to regional levels.

In 2016-2018, new tools to collect, process, analyze and share time-synchronized flux data from multiple flux stations were developed and deployed globally. Originally designed to automate site management, streamline data quality control and analysis, these tools allow relatively easy matching of tower data with remote sensing data due to GPS-driven time protocols and sophisticated footprint analysis tools. Moreover, current flux stations can be augmented with advanced ground-based optical sensors to deliver continuous products (e.g., NDVI, PRI, SIF, etc.) valuable for remote sensing and modeling, seamlessly logged and time-matched together with flux, weather and soil data.

Over 100 of new flux stations already operational globally can be readily used for the proposed workflow. Over 500 active traditional flux stations can be updated to synchronize their data with remote sensing measurements.

This presentation will describe the latest on how these new tools are used by major networks, and describe how this approach can be utilized for matching remote sensing and tower data to aid in ground truthing, improve scientific interactions, and promote joint grant writing and other forms of collaboration between the flux and remote sensing communities.

Carbonyl sulfide and sun-induced fluorescence as joint constraints on terrestrial carbon cycling

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Terrestrial gross primary production (GPP) plays a critical role in offsetting anthropogenic carbon dioxide (CO_2) emission and decreasing the rate of the associated global warming. However, its magnitude is highly uncertain due to conceptual and methodological difficulties in disentangling GPP and ecosystem respiration (Reco) from eddy covariance (EC) flux tower measurements of net ecosystem exchange (NEE) of CO_2. Such an uncertainty in carbon-climate feedback is a major source of uncertainty when modeling future greenhouse gas forcing and climate change. In recent years, technological progress in quantum cascade lasers and high-resolution field spectrometers have enabled the use of alternative tracers for constraining ecosystem-scale photosynthesis, i.e. carbonyl sulfide (COS) and sun-induced fluorescence (SIF), respectively. COS has been proposed as a potential tracer of GPP, as it diffuses into leaves in a very similar fashion as CO_2, but in contrast to the latter, there is no concurrent COS efflux from the vegetation canopy. The principle underlying the use of SIF as a tracer of GPP is based on the fact that photosynthesis and SIF compete for the same excitation energy.

This study presents the concept and the first results of an ongoing H2020-MSCA-IF COSIF project aiming at providing new independent constrains on GPP by concurrent ecosystem-scale EC-COS and SIF measurements at three contrasting European ecosystems, including a temperate mountain grassland, and deciduous and evergreen forests. Presented results refer to the dynamic grassland site (AT-Neu), in which optical and EC measurements were accompanied with active chlorophyll fluorescence, fraction of absorbed photosynthetically active radiation, leaf area index and chlorophyll content measurements.

Flux partitioning plus – joint constraints by carbon dioxide and carbonyl sulfide increase inferred gross primary productivity estimates

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The trace gas carbonyl sulfide (COS) has been proposed as a tracer for canopy gross primary production (GPP) in the last few years as it enters plants in a similar way as carbon dioxide (CO2) but is taken up in a one way reaction. Although non-plant COS sources and sinks e.g. soils complicate the implementation of COS as a tracer for GPP on ecosystem level, the one-way flux into the leaf makes COS a promising GPP constraint. The overarching objective of this study was to evaluate the potential of COS as a tracer for GPP and improve current flux partitioning (FP) models by implementing COS as an additional constraint for the plant canopy CO2 exchange. To obtain our goal, we conducted campaigns at different field sites across Europe. These sites included a managed temperate mountain grassland, a savanna, a temperate beech forest and a soy bean field. On each of these sites we conducted ecosystem scale eddy covariance and manual soil chamber measurements of COS and CO2. The soil COS flux reached emissions of up to 11 pmol/m2s during daytime at grass dominated ecosystems. During nighttime we observed fluxes close to zero. Since the magnitude of the soil fluxes, which was strongly correlated to incoming shortwave radiation, could not be neglected, these were subtracted from the ecosystem flux to derive the actual canopy COS fluxes for all the measurement sites. Our data confirm previous studies showing that the leaf relative uptake (LRU) is a light dependent variable but is also varying between ecosystems and can therefore not be used as a constant in models. The joint constraint by both CO2 and COS resulted in higher values for GPP which suggests that GPP estimates derived from current FP models are likely to underestimate the magnitude of GPP.

Atmospheric GHG measurements onboard voluntary observing ships (VOS) - approaches for improved atmospheric sampling

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Autonomous systems measuring the partial pressure of CO_2 (pCO_2) in surface waters on commercial carrier ships (Voluntary Observing Ship, VOS), which allows for high spatiotemporal data coverage, are a major component of the Ocean Thematic Centre (OTC) data stream. Currently, ICOS operates lines in the Atlantic, North Sea and the Baltic. All lines are determining pCO_2 by measuring CO_2 in air that has been equilibrated with seawater.

As part of the European H2020 project RINGO (https://www.icos-ri.eu/ringo), we are evaluating the possibility of using VOS to expand the atmospheric network. We will provide technical solutions for three different settings and approaches, and assess the added value for the atmospheric observation network. Two systems are designed as stand-alone modules for continuous atmospheric CO_2 and CH_4 measurements, following the technological requirements defined by the ATC, and will be operated in the Baltic (high anthropogenic influence) and on a line between France and Brazil (clean marine air, large temperature and humidity gradient). A second approach is using the existing instrumentation for seawater measurements (North Atlantic), which we aim to improve in order to make these measurements usable for the atmospheric research community.

This is an effort that connects the ocean research community with the Central Analytical Laboratories (CAL; testing an extended range of standard gases, providing flask sampling opportunity), the Atmospheric Thematic Centre (ATC; work on data streams that can be digested by the ATC system), and the modelling community (identifying useful sampling strategies). Here we present a status update of the ongoing work, which is a joined effort of the atmospheric and ocean community within ICOS and relying on the expertise of both fields.

Quantification of methane emissions from dairy cows in the Netherlands

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Methane (CH4) emissions are a major contributor to the total European greenhouse gas emissions; however, these emissions are not well quantified. As part of the Methane goes Mobile – Measurements and Modelling (MEMO2) project, we aim to quantify agricultural CH4 emissions (cattle, i.e. enteric fermentation and manure). In the Netherlands, these account for ~ 67% of the total emissions in the Netherlands in 2015, of which enteric fermentation contributed 44%, and manure 23%. Within this project we aim to use an active AirCore system on an unmanned aerial vehicle (UAV) to obtain spatial and temporal variations of atmospheric CH4 mole fractions, which will allow us to accurately determine the source strength.

We present the results from three field campaigns. One was performed at a dairy cow farm in the Netherlands using a mobile van to obtain multiple near-surface transect measurements in February 2018. A Gaussian plume model was used to calculate the emission rates. The other two field campaigns were performed on a nearby but different dairy cow farm in the Netherlands, in March 2017 and in May 2018, respectively. At this farm vertical profile measurements of CH4, CO2 and CO were made upwind and downwind using an UAV AirCore system, which had improved spatial resolution compared to 140 Torr mode by using a low-cavity mode (80 Torr) of the CRDS analyzer. From the difference between the measured upwind and downwind CH4 mole fractions, we calculate the methane enhancement, and subsequently use a mass balance approach to determine the CH4 emission rates from the dairy cow farm.

Finding the best way to sample using an Ecotech Spectronus FTIR instrument

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Ecotech Spectronus FTIR instruments allow to measure CO2 and its isotopes, CH4, CO and N2O at great precision compatible with ICOS atmospheric needs. Two ways of sampling are possible: either the sample is continuously flowed through the cell and measured at the same time, or for each sample period, the cell is filled and closed after a flushing period with measurement during the static closed cell period. The second option allows for a lower gas consumption, which can be critical as the sampling cell is rather large and ICOS atmospheric requirements ask for regular calibrations and control gas measurements. Here, we present results from tests aiming at finding the best strategy for the use of this instrument in ICOS. Two main questions are addressed: what is the optimal flushing and measurement time when closing the cell and is the internal drying system used in the instrument having an effect on the measurements?

Automatized Soil Evapo-Respiration Chamber (ASERC)

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One of the widely used technologies to measure the greenhouse soil fluxes is the Accumulations Chambers (AC). The potential fluxes are computed from a cumulated gas mixing ratio measured inside the chamber based on a dynamic closed system.

While that methodology is recognized as a reference approach for many decades [1], it also presents several disadvantages by biasing the measurement in different way depending on the set up (shape and dimension of the chamber, aerodynamic conditions [2], data processing [3] and so on). The ASERC chamber was developed to overcome all the possible biases making the measurement conditions as close as possible to the reality and correcting the inherent discrepancies. From the construction, the choice of the materials used, to the operation protocol, as well as the choice of data processing, all components were tested. Embedded fast sensors are used to directly capture the air moisture inside the chamber and the carbon dioxide mixing ratio. The system was also calibrated on sandy soil for different evaporation regimes and external wind of various intensities. In that study main experimental issues and possible solutions are addressed. A good agreement between both methods used, ASERC system versus measures by weighing of soil sample evaporation, was found.

[1] Lundergårdh H., Soil Science. 23: 417-453, 1927,"Carbon dioxide evolution of soil and crop growth"

[2] Le Dantec et al, Plant and Soil 214: 125–132, 1999, "Soil CO2 efflux in a beech forest: comparison of two closed dynamic systems".

[3] L. Kutzbach and al, Biogeosciences, 4, 1005–1025, 2007, "CO2 flux determination by closed-chamber methods can be seriously biased by inappropriate application of linear regression"

Oral Presentations for Session 9: Land sink – from residual to direct estimates

Conveners: Markus Reichstein

Focus is on advances in the transition from estimating the land sink as residual of other components to estimation based on observations.

Increasing soil respiration has threatened the carbon sink at a northern boreal fen

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Climate warming is strongest at the high northern latitudes. As peatlands store a vast amount of carbon in the form of peat, their response to warming is of particular interest. Peatlands contribute to atmospheric carbon dioxide (CO_2) and methane (CH_4) concentrations by fixing CO_2 in photosynthesis and releasing it through respiration by plants and dead peat material, and by emitting CH_4. As climate warming impacts these processes differently, long-term monitoring of both gases is essential to predict the behaviour of the peatland ecosystems and their carbon store in the future. Here we will present a ten-year (2007-2016) data set of CH_4 and CO_2 exchange fluxes of a northern boreal fen measured with the eddy covariance method. The site, 'Lompolojänkkä' is located in Finland within the Pallas area (67°59.832'N, 24°12.551'E, 269 m above sea level) 160 km north of the Arctic Circle. Within this area the mean annual average temperature has increased by 2 °C in 40 years. Our results show that while the gross primary production and annual CH_4 balances have stayed unchanged during the last 10 years. However, the total ecosystem respiration shows an increasing trend, and consequently the annual net CO_2 uptake has decreased during the 10-year study period. The strongest warming has occurred in autumn, which has increased the net CO_2 emission during this period. During winter, spring and early summer, small or no changes in gas balances were observed. During the most recent warm years, the carbon balance, i.e. the sum of CO_2 and CH_4 exchange, was close to zero. Thus our results suggest that climate warming decreases the net CO_2 uptake of a boreal fen through increased ecosystem respiration, while CH_4 emissions stay unchanged.

Flooding-induced N_2O and CH_4 fluxes from soil to tree level

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Estimation of carbon and nitrogen storages and fluxes in different forest ecosystems under different environmental conditions is essential to understand their capacity of carbon sequestration. Flash floods are predicted to become more frequent in future climates, change soil redox potential and alter greenhouse gas fluxes. Further, plant species react differently under stress conditions, for instance depending on stressing event characteristics.

In 2017, we conducted an experiment to simulate flooding stress in order to estimate forest ecosystems response to flooding effect on N_2O and CH_4 fluxes from soil and through tree stems.

The study site was located at a 40-years old grey alder stand in Estonia, consisting of the artificially flooded (FP), and a control plot (CP). Three periods were investigated: pre-flooding (four weeks), flooding (two weeks), and post-flooding (four weeks). In total, twelve trees (FP: 9, CP: 3) were equipped with manual static stem chambers (0.1, 0.8 and 1.8 m from ground). During 25 campaigns (three times per week at daytime, once per week at night-time) gas samples were collected and analysed in laboratory. In addition, automated dynamic ground chambers (soil N_2O and CH_4), piezometers for water samples, automatic groundwater level wells, soil temperature and moisture sensors were installed close to each sampled tree. Composite soil samples were taken for physical and chemical analysis.

Soil fluxes showed similar pattern with tree chambers, being elevated during the flooding and post-flooding period. Further, stem CH_4 decreased with the tree height. N_2O fluxes from the bottom level of the tree significantly increased during flooding, whereas decreased with increasing stem height.

The night time flux dynamics show similar pattern, however with lower values compared to daytime.

Our results show that stem fluxes, especially during extreme events such as flooding, contribute to forest both nitrogen and carbon cycles and must be included in relevant models.

Nitrous oxide (N_2O) and methane (CH_4) fluxes of boreal tree species and their seasonal dynamics

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The increase in atmospheric nitrous oxide (N_2O) and methane (CH_4) concentration contributes to the acceleration of the greenhouse effect. Plants are known to emit both gases; however, the role of trees, especially upland trees, in the forest ecosystem N_2O and CH_4 exchange is still not well understood.

We determined N_2O and CH_4 fluxes in common boreal tree species: Scots pine (Pinus sylvestris), Norway spruce (Picea abies), and downy and silver birch (Betula pubescens, B. pendula). We investigated (1) whether these tree species exchange N_2O and CH_4 with the atmosphere, (2) the extent to which the trees contribute to net ecosystem N_2O and CH_4 exchange, and (3) the seasonality of these fluxes.

The study was performed in a boreal forest (SMEAR II, Finland; June 2014-May 2015). Fluxes of N_2O and CH_4 in mature tree stems and forest floor at three plots naturally differing in soil volumetric water content (VWC) were measured using non-steady-state chamber systems followed by chromatographic analyses of gas concentration changes.

Pine, spruce and birch stems were identified as net annual sources of N_2O and CH_4. Spruce stems were found the strongest N_2O emitter (2.4 g ha^{-1} yr^{-1}) amounting up to 2.5% of forest floor N_2O emissions. All tree species showed a substantial seasonality in stem N_2O fluxes which was related to physiological activity of trees. Birch grown under high VWC (0.81 m^3 m^{-3}) was the strongest source of CH_4 (467 g ha^{-1} yr^{-1}) corresponding to 28% of the forest floor CH4 emissions. The pine and spruce emissions (4–35 g ha^{-1} yr^{-1}) were not affected by VWC. The forest floor was a sink for CH_4 under low VWC (< 0.4 m^3 m^{-3}). All tree species emitted CH_4 mainly during the vegetation season with considerable emissions detected already from February onwards.

Imprint of nutrient availability on ecosystem functional properties

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Semi-arid ecosystems play a major role for the global carbon cycle due to their large spatial extend and their strong influence on the interannual variability of the terrestrial carbon sink. One factor influencing the carbon uptake by the vegetation is the nutrient availability and their stoichiometry. Due to the human induced increase in atmospheric nitrogen deposition, phosphorous, the second most important macro-nutrient after nitrogen is likely to become a limiting factor. To analyze the impact of nutrient imbalance on semi-arid ecosystems the MaNiP experiment was conducted. It is a large scale nutrient manipulation experiment for which the flux footprints (24 ha each) of two out of three collocated eddy covariance towers were fertilized with nitrogen (N) and nitrogen plus phosphorous (NP), respectively. The third tower, the long term FLUXNET site ES-LMa, serves as the control (C) and was not fertilized. The ecosystem is an open woodland with roughly 20 % of tree canopy cover (Quercus ilex) and grasses, forbs, and legumes in the herbaceous stratum. The experiment started in 2014 with a one-year control period to evaluate systematic differences between the three footprint areas.

This work presents results from the first four years of the experiment, focusing on the effects of the fertilization on ecosystem functioning and how nutrient limitation can affect ecosystem functional properties. Both fertilized treatments significantly increased the carbon uptake, but the N treatment showed significantly larger water vapor fluxes then the NP and C treatment. Additionally, the fertilized treatments had lower surface temperatures, mainly due to changes in albedo and energy fluxes.

The stoichiometric imbalance of nitrogen and phosphorous led to less efficient photosynthesis, with respect to water-use-efficiency and changes in surface temperatures. Especially, the additional loss of water through transpiration will strongly affect semi-arid regions and maybe cause negative feedbacks for the terrestrial carbon sink.

Water-atmosphere exchange of greenhouse gases (CO_2, CH_4, N_2O) in two major river systems - the Elbe (Europe) and the Murray (Australia).

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Global greenhouse gas (CO_2, CH_4 and N_2O) emissions from inland waters are significant yet estimates remain highly varied and are quoted with large uncertainty. For example, recent CO_2 estimates range from 0.75 – 3.3 Pg C yr^{-1} and are comparable in magnitude to the global net uptake of CO_2 by the land or ocean sinks. However, these estimates are not adequately constrained by small scale measurement data, particularly for CH_4 and N_2O, which have received far less attention than CO_2.

Here we present in-situ measurements of inland water-atmosphere greenhouse gas exchange obtained over several hundred kilometres on the Elbe (Germany/Czech Republic) and Murray (Australia) Rivers. Greenhouse gas partial pressures (pCO_2, pCH_4 and pN_2O) were measured continuously at high spatiotemporal resolution using an equilibrator coupled to a Fourier-Transform InfraRed (FTIR) Trace Gas Analyser. Water-atmosphere greenhouse gas exchange was measured directly using floating chambers coupled to the FTIR. Gas transfer velocities were derived from greenhouse gas partial pressure and water-atmosphere exchange measurements, and were also modelled based on wind speed and hydrology using an ensemble of nine commonly applied parameterisations. A suite of biogeochemical parameters (e.g. pH, DO, DOC and DIN) were also measured to gain further insight into the broader mechanisms driving greenhouse gas exchange.

This presentation will reveal the high spatio-temporal variability of water-atmosphere greenhouse gas exchange observed along the land to ocean aquatic continuum. Significant drivers of variability will be discussed, including diurnal cycling, connectivity with floodplain wetlands, water regulation and discharge from wastewater treatment facilities. Finally, this research will provide the first estimates of the water-atmosphere greenhouse gas exchange from two globally significant inland water systems.

Posters for Session 9: Land sink – from residual to direct estimates

Investigations on the energy balance closure and energy partition over cropland with long-term experimental data

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The non-closure of the surface energy budget, when using eddy-covariance technique to estimate turbulent fluxes, is still an unresolved problem [1], [2]. This study relies on the data collected during 10 years (2006-2016) in a temperate cropland site (at Lamasquère FR-Lam, southwestern France which is an ICOS Ecosystem site) with a winter wheat and maize rotation. Using continuous EC measurements of evapotranspiration and sensible heat fluxes, completed with meteorological, soil and biophysical measurements allowed a multivariate analysis of the closure of the energy balance. Both imbalance and flux partition are analysed with regard to the condition of the surface (tillage), the type of crops and their stage of development. In addition to the influence of the canopy growth and soil state, we also investigated the effect of turbulence (through the friction velocity u*) and atmospheric conditions (stability index). We also estimated the storage terms and their impact on the closure of surface energy balance. Finally, the comparison of energy partition, its inter-annual variability and its seasonality are discussed for both maize and winter wheat.

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Integrating remote sensing and eddy covariance to assess net ecosystem carbon balance in a Mediterranean cork oak woodland

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In seasonally dry climates, like Mediterranean, variations in climatic conditions are more likely to induce significant changes in ecosystem–atmosphere CO2 fluxes, such as gross primary production (GPP) and ecosystem respiration (Reco), disrupting the net ecosystem exchange (NEE). As drought periods are projected to increase under climate change scenarios it is crucial to understand the mechanisms behind ecosystem-atmosphere exchange. Models integrating remote sensing information are increasingly applied for ecosystem monitoring. However, in Mediterranean cork oak woodlands the coexistence of different plant functional types hampers the remote sensing data application.

Here, we investigated the effects of seasonal and inter-annual variation in carbon fluxes, climate and vegetation indices in a Mediterranean woodland, using in situ eddy-covariance and hyperspectral measurements and remote sensed data. The study period, from 2010 to 2017, was characterised by high intra- and inter-annual climatic variation, with the hydrological pattern driving the productivity of the ecosystem. The hydrological years 2011–2012 and from 2014 to 2017 (3 years) had reduced precipitation (up to -55%, when compared to the 30 years average) which lead to a significant reduction (p-value < 0.001) in GPP and Reco and a reduction in the ecosystem's carbon sink potential. Moreover, we concluded that not only the inter-annual hydrological variation influenced the ecosystem, but mostly the seasonal pattern, with reduced rain in winter being more detrimental than in any other season. The intra-annual variations in precipitation seem to have a higher impact in the ecosystem productivity than a prolonged drought period.

When composing the climatic data and the vegetation indices, we observed a similar tendency, with the hydrological pattern leading the phenological changes observed, mainly in the herbaceous vegetation. Future work will converge in the integration of the spectral data into productivity models, employing the eddy-covariance data as optimization of parameters.

Image classification to improve the estimation of GHG emissions through mapping of archetypical vegetation in the savannahs of Brazil

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Since the pre-industrial era, the principal contributors to greenhouse gas (GHG) emissions have been human society and its activities. During the last decades, emissions from tropical deforestation to the global carbon pool have increased, as large areas of savannah and wetland have been replaced by pasture and agricultural land at unprecedented rates. Since ecosystem productivity estimation depends on knowledge about the location and extent of its different components, it is fundamental to correctly represent the spatial distribution of vegetation types to estimate accurate GHG emissions associated with deforestation from these areas. In this context, the objective of the present work was to map the archetypal ecosystems of the Brazilian Cerrado (a savannah region) using Landsat images, aiming to reduce the uncertainty of land cover change emissions modeling. To do this, we first use a mask of human-influenced areas and water bodies. Then, masked 30 meter-resolution Landsat images from the Cerrado's savannahs were used to generate Linear Models of Spectral Mixture. Spectral thresholds are thus defined for three archetypes of vegetation (woodlands, shrublands and grasslands) and used to classify for classification through image-slicing. In addition, the map adequately included areas not originally observed due to the presence of clouds and their shadows. The resulting classified-images were vectorized, smoothed and visually inspected. Results show the distribution of the areas covered with natural vegetation divided into the three main types of vegetation and their relation with the total area of the biome. The data will be used to detail the Cerrado's phytophysiognomies, to associate spatially explicit information of biomass density and thus provide more accurate GHG estimations related with deforestation in the scope of the "Development of systems to prevent forest fires and monitor vegetation cover in the Brazilian Cerrado Project" financed with funds from The World Bank IBRD-IDA.

Response of soil CO2 emissions to different wetting intensities in a grassland ecosystem

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Whilst it is well known that rainfall events can stimulate CO_2 emissions (i.e. the Birch-Effect), its contribution to annual C emissions remains largely unquantified, as does the impact of different rainfall amounts/wetting intensities, particularly at the field scale. In this study, the short-term impact of simulated rainfall amounts on soil CO_2 emissions from a coastal grassland ecosystem were investigated for summer and autumn periods and the information used to assess their impact on annual CO_2 emissions. Higher cumulative CO_2 emissions of a longer duration were found with increasing wetting intensity and higher wetting intensities resulted in significantly greater emissions than smaller ones. For a range of higher wetting intensities, the cumulative emissions were largely independent of wetting intensity. Inverse correlations between cumulative CO_2 emissions and soil moisture content prior to water addition (InitSWC) were found for all wetting intensities. Also, a significant inverse relationship was found when all the data ($R^2 = 0.37$, $P < 0.001$) were combined, although a better fit was obtained when lower wetting intensities were omitted ($R^2 = 0.68$, $P < 0.001$). This indicates that factors associated with soil drying, prior to water addition, which presumably enhances the availability of C substrates for microbial processes, have the major impact on CO_2 emissions, particularly at higher wetting intensities.

Disentangling soil water movements to improve the forecast of drought impact on forest ecosystems

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Water availability for plant growth is a critical issue in a changing climate. Water availability determines ecosystem responses to drought events and the corresponding vegetation feedback on climate. However, several processes complicate the plausible forecast of soil water storage and fluxes in ecosystem models. Among the critical processes, preferential water flow, root growth and root water uptake influence plant available soil water. These processes are not well represented in ecosystem models. Our objective is to improve the simulation of plant water availability in the ecosystem model MuSICA. We use a long-term dataset of chloride concentrations in soil water in a French beech forest together with modelling experiments to disentangle matrix flow, preferential flow and root water uptake. Here, we describe the long-term chloride dataset and preliminary information we can extract from it. Chloride enrichment at the top and the bottom of the soil profile suggests solute discrimination during evaporation and root water uptake, respectively. We then present our model developments to include chloride transport through matrix and preferential flow and chloride uptake in MuSICA and the results of validation test cases. Subsequently, we show how model experiments and model-data comparisons can be used to understand water movement in the soil-plant continuum at the study site. Finally, we explore how a better representation of soil water fluxes influences the forecast of ecosystem responses during drought events.

CO_2 fluxes before and after partial deforestation of a spruce forest

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Forest ecosystems are a sink for atmospheric CO_2, but can weaken or turn into a source due to disturbances such as deforestation. Later, the recovering vegetation may be a weaker or stronger sink than the original forest. Changes in albedo additionally modify the total climate effect.

We present seven years of flux measurements sampled above a spruce (picea abies) monoculture at the ICOS associate station candidate DE-RuW (50°30'N, 06°19'E, 600 m a.s.l.). The monoculture originally covered the whole headwater catchment (38.5 ha), which is highly instrumented in the framework of TERENO (TERrestrial ENvironmental Observatories). Three years after the start of measurements, 9 ha outside the main footprint of the tower were deforested to promote natural succession towards deciduous forest. A second eddy-covariance station was installed in the centre of the clearcut and soil respiration of both ecosystems measured manually at monthly intervals. Finally, we compared the climate effect due to changed CO_2 sequestration with the biophysical one due to changed albedo.

Annual sums of NEE measured above the forest showed a strong carbon sink with small inter-annual variability (-660±78 g C m^{-2} y^{-1}). Over the four years since deforestation, the initially almost bare clearcut overgrew with grasses, shrubs and young deciduous trees (mostly rowan, sorbus aucuparia). The recovery is reflected by annual sums of NEE, which decreased from a carbon source of +521 g C m^{-2} y^{-1} towards almost neutral (+83 g C m^{-2} y^{-1}). Soil respiration of the clearcut resembled the one of the forest floor during the first two years, but then became significantly higher during summer months as GPP increased. In terms of global radiative forcing, an immediate biophysical cooling effect of the deforested area, due to higher albedo of the soil and recovering vegetation, still overrides the cumulating biochemical effect of the missing CO_2 sink.

An assessment of differences in Carbon Sequestration capacities of selected tree species in the rainforest belt of Southwestern Nigeria

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Although, the tropical forest is known to be a significant terrestrial carbon “sink”, there is limited knowledge about capacities of specific tropical trees for carbon uptake. This study investigated the capacities of plant communities dominated by three different tree species in the rainforest belt of southwestern Nigeria. Plantations of Theobroma cacao, Cola nitida and Tectona grandis between 11 and 60 years of age were studied. A 60 year old primary forest near the three plantations was used as control. Five 20 m by 20 m quadrats were demarcated in each plantation and the control. Soil samples were taken from them and the carbon content analysed. Vegetation physiognomic parameters were measured to estimate carbon content of above ground biomass. Data obtained were converted to carbon stocks using allometric relationships with the biomass-diameter-regression model. T. grandis plantation over 40 years old accumulated most carbon in its biomass. Compared with the primary forest, C. nitida below 40 years sequester the highest (30.5 g/kg) amount of carbon in soil while T. cacao trees less than 40 years had the least (19.3 g/kg). T. grandis had the highest carbon in its leaf litter on plots less than 40 years while C. nitida had the highest on plots of over 40 years. Tectona grandis was the most efficient carbon sink of the species investigated. In the plantations, the older the tree, the higher the potential to sequester carbon. In order to increase carbon sequestration, the cultivation of T. grandis in plantations is most appropriate where it can be made the choice tree species.

Response of wetland GHGs exchange to climatic extremes – results of 5-year EC measurements of H_2O, CO_2, CH_4 fluxes in Biebrza National Park, Poland

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Natural wetlands are a significant source of methane and a sink of carbon dioxide. However, changing environmental conditions can disturb this picture. Drainage of the mires and lowering of the water level reduce ecosystem net productivity and methane production. We present results of 5-year (2013-2017) open path eddy-covariance measurements of energy balance and CO_2 and CH_4 fluxes at the mires of Biebrza National Park (northeastern Poland) – one of the biggest wetlands in central Europe. The measurement site was located in the central basin of Biebrza valley on the large, flat surface near to the village Kopytkowo (53º35'30.8"N, 22º53'32.4"E, 110 m a.s.l.).

During the measurement period, year 2015 was extremely dry, whereas year 2013 was relatively wet in the long-term perspective. The results show that Biebrza mires exhibit a high sensitivity to the climatic condition mainly to the water table level. In year 2013, the wetland was a significant sink of carbon dioxide with annual uptake reaching almost 1000 $gCO_2\ m^{-2}\ y^{-1}$ whereas in extremely dry year 2015 we recorded net CO_2 release about 500 $gCO_2\ m^{-2}\ y^{-1}$. The annual methane release, was on the level of 29 $gCH_4\ m^{-2}\ y^{-1}$ in 2013, and

dropped below 5 $gCH_4\ m^{-2}\ y^{-1}$ in dry years. At the same time only little differences between wet and dry years were recorded in latent heat flux (evapotranspiration).

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Eddy covariance CO_2 flux measurements reveal below ground carbon allocation as an overlooked climate service of short rotation coppice bioenergy cropping.

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Using biomass rather than fossil fuel is one option to mitigate climate change, given the demand for organic material and energy. New perennial biomass production systems are being increasingly established. Beyond their productivity, little is known about the carbon cycling and storage in such systems, making it difficult to assess the life cycle environmental impacts.

In 2010 we established a willow short rotation coppice (SRC) on former agricultural land of the DTU Risø campus, Zealand, Denmark (DK-RCW). From 2012, we continuously measured net CO_2 fluxes (NEE) with the eddy covariance method. NEE data were partitioned into ecosystem respiration (RE) and gross primary productivity (GPP). Data from two harvests and six years, i.e. 2 full rotation cycles, were used to describe the carbon flows and budgets in the SRC.

The most important results was that the net carbon uptake into the planation was considerably larger than the carbon export with harvesting. This is interpreted as a below ground net carbon sequestration, either in the developing root system or increasing the soil carbon stock. While the GPP varied only little across years, the RE increased steadily, causing a steady decline of the annual NEE values. The increase of respiration is interpreted as a consequence increased below ground respiration, either autotrophic, heterotrophic or both.

The belowground sequestration of atmospheric CO_2 is a hence overlooked climate service, because this carbon is not contributing to global warming as long as it stays in the SRC system. Comprehensive life cycle assessment must take the below ground carbon allocation into account. Further research is needed to determine the fate and the stability of the sequestered carbon. The results show the importance of continuous long-term CO_2 flux measurements for the assessment of climate change mitigation strategies with terrestrial ecosystems.

Aerenchymous plant species differ in their CH_4 transport in Siikaneva boreal peatland

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Boreal peatlands act as natural sources of methane (CH_4) to the atmosphere due to their wet anoxic conditions. Release of CH_4 from the anoxic peat layers to the atmosphere occurs mainly through three transport routes; diffusion, ebullition and plant transport. The proportions of these transport routes has a significant impact on the total amount of CH_4 released, as in ebullition and plant transport CH_4 bypasses the methanotrophic microbia of the oxic peat layers. Transport of CH_4 through aerenchymous plants is known to account for 30-100% of the total CH_4 emissions of a peatland site. However, the differences among plant species in their CH_4 transport capacity and species' roles for the site-level CH_4 emission over the growing season are rather poorly known.

We used a plant exclosure chamber to quantify the CH_4 released through individual stems of aerenchymous peatland plant species. The measurements were conducted in the oligotrophic fen and ombrotrophic bog parts of boreal Siikaneva peatland complex in Southern Finland during the growing season of 2014. To find out about the interannual variability of plant-mediated CH_4 transport, the measurements were also done in the ombrotrophic bog in 2013. The CH_4 emission rates of the aerenchymous plant species per gram of dry mass differed but the emission did not vary within the growing season. As species differ in their seasonal leaf area development, also their roles for the site-level CH_4 emission varied over the growing season.

Assessing spatial patterns of ecosystem productivity and diversity in grasslands using Sentinel-2: is it feasible?

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Combining in-situ and remote sensing data to understand across-scale interactions between ecosystem diversity and productivity -in a changing climate- is fundamental. Each plant species is characterized by unique biochemical, structural, and functional properties, which translate into canopy-level optical diversity, which in turn is associated with ecosystem biodiversity. Novel high-resolution remote sensing tools may be adopted to explore biodiversity and productivity relationships (BPRs) over large areas, however only sporadic experimental remote sensing studies have been carried out to analyze the scale-dependency of BPRs, and more studies are needed to verify the suitability of current remote sensing data for such analyses.

In this context, a combined analysis of spatial patterns of grassland productivity and diversity data was performed in this study by integrating the remote sensing and eddy covariance techniques. Canopy structural and biochemical controls on productivity were investigated, and across-scale BPRs patterns were analyzed for five different grasslands of the Italian Alps characterized by a wide range of productivity. Using AISA Eagle airborne optical data to simulate Sentinel-2 spectral bands, a positive relationship between productivity and optical diversity was demonstrated for these sites. A correlation analysis was carried out at increasing pixel size by resampling the AISA Eagle data and a clear scale-dependency of BPRs was detected. The satisfactory results obtained at 20 m spatial resolution demonstrated the strong potential of Sentinel-2 for monitoring BPRs patterns and for upscaling them to upper levels of observation.

Can the restoration of bogs drained for forestry-use contribute to climate change mitigation?

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Few data are currently available on forested bog sites in Germany; possibly, because bog forests are a relatively uncommon ecosystem there: Forests on organic soils (i.e. bogs and fens) make up only about 3.2 % of Germany's national territory. Furthermore, it is difficult to quantify greenhouse gas fluxes for this ecosystem. Nevertheless, within the scope of national greenhouse gas reporting reliable emission factors for different ecosystems and land-use types are important. Missing data on forested bogs in the temperate climate zone therefore constitute a research gap that needs to be closed. Recently, forests on organic soils have been reported with an emission factor of 24 t CO_2eq ha^{-1} a^{-1}. Restoring bogs which have been drained for forestry-use could be a means of climate change mitigation. In this study, we compare the carbon balance of a drained forested bog site (ICOS associated site Mooseurach) with a near-natural pine bog forest (ICOS associated site Schechenfilz). A windbreak occurred at the Mooseurach site in January of 2015 and the remaining trees were subsequently clear-cut in December of 2015. As the forest there is no longer managed, the windbreak offers the unique possibility to study the greenhouse gas balance of natural succession. Moreover, comparing the results with those of the Schechenfilz site provides the opportunity to estimate the climate change mitigation potential of actively restoring the drained site towards natural conditions. At both sites we have used eddy covariance measurements to quantify carbon dioxide fluxes since 2010 and methane fluxes since 2012 (Schechenfilz) and 2015 (Mooseurach), respectively. In addition to the flux measurements, we try to establish relationships with different ancillary variables such as water table and soil temperature. Our overall goal is to determine if greenhouse gas emissions might be avoided if drained bog sites were restored to a natural state in Germany.

Compilation and analysis of carbon balance of a six-year-old Scots pine (Pinus sylvestris) stand by using two different methods

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Forests role in global carbon (C) cycle and climate mitigation is crucial both at global and regional level. The forest management has an important impact on forest ecosystems functioning and on their C sequestration ability. Clear-cutting is a conventional forest management method which changes the C cycling in ecosystem level to great extent for a long period. In this study, we measured net ecosystem exchange (NEE) directly and examined changes in C fluxes and stocks separately. The study site (Myrtillus) is located in the South-Eastern part of Estonia, in Tartu County (58°17’01.0” N, 27°09’43.0” E). The total area of regenerated clear-cut is 2.1 ha. In 2015-2016, we measured NEE, soil heterotrophic respiration and methane flux, TOC leaching and different environmental parameters. We estimated above- and belowground biomass and production of trees and understorey. The annual NEE measured with eddy covariance (EC) technique was 1.18 t C ha^{-1} yr^{-1} while the C budgeting method showed a similar value, the ecosystem loss: 1.38 t C ha^{-1} yr^{-1}. Most of the C was sequestered in plant biomass: above- (tree biomass increment, production of understorey) and belowground (coarse root biomass increment, tree fine root production, understorey root and rhizome production) 2.28 and 0.55 t C ha^{-1} yr^{-1}, respectively. However, the highest C loss was heterotrophic respiration: 4.2 t C ha^{-} yr^{-1}. To conclude, a six-year-old Scots pine stand is a weak carbon source but already next year C fixation will most probably exceed C loss due to the increased biomass production of young trees. Hence regenerated Scots pine forest of Myrtillus site type can turn to C sequestering ecosystem already in less than 10 years after cutting. Both EC and C budgeting method gave reliable results. However, in situ estimation of all C fluxes is necessary for better understanding of ecosystem processes and modelling.

Factors determining transpiration of five main European tree species grown in various forest ecosystems

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Water use of forest stands through transpiration is an important ecosystem function that corresponds to other physiological processes, such as carbon assimilation and respiration. Forest transpiration is determined by microclimatic conditions, water availability, stand structure and species composition. Our study goal was to analyse species-specific characteristics of tree water use and its response to changing environmental conditions. Four forest stands: young mountain spruce monoculture, mature spruce upland monoculture, mature pure beech forest and mixed floodplain forest were investigated during the growing season 2017. There, five tree species: Picea abies, Fagus sylvatica, Quercus petraea, Fraxinus excelsior and Carpinus betulus were compared. Transpiration was measured using sap flow-based tissue heat balance method. Tree water use was evaluated with microclimatic conditions (particularly VPD, global radiation, potential evapotranspiration) and soil water availability. Species sensitivity to changing evapotranspiration demand and level of stomatal control were analysed. The correlation between tree size, its social position within a stand and mean transpiration was also investigated.

The studied species differed significantly in tree transpiration. There was a strong correlation between transpiration and tree social position for all studied species. In relation to tree size, transpiration was the lowest in Picea abies, followed by Fagus sylvatica, Fraxinus excelsior and Carpinus betulus. Quercus petraea transpired the most from studied species. We observed significant differences in sensitivity of species to changing microclimatic conditions, particularly VPD and global radiation. The lowest correlation between transpiration and microclimate was found for Fraxinus excelsior. This study indicates important differences in water use by various tree species, which needs to be taken into account in further studies of ecosystem water relations.

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Carbon budget of a temperate-climate vineyard: three years of observations at IT-Lsn

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Long-term flux observations on agricultural ecosystems are still scarce compared to forests or other natural ecosystems. However, the monitoring of vegetation-atmosphere exchanges over crops gives valuable information on the role of this production sector on global biogeochemical cycles. Additionally, continuous measurements of GHG fluxes are essential to evaluate the effect of different management practices, providing guidelines for farmers and policy makers on the best practice to adopt to increase environmental sustainability. Indeed, agriculture can play a positive role in the global carbon budget through reduction of emissions and increase of soil carbon sequestration.

Perennials, in comparison with annual crops, have some biological, structural and management peculiarities (e.g. reduced tillage, grass-covered alleys), which allow them to potentially sequester more CO_2 from the atmosphere. Nevertheless, only few studies have been conducted over this kind of ecosystems. Here, we present three years of CO_2 fluxes (May 2014-April 2017) on a vineyard in North Eastern Italy, which is a candidate ICOS class 2 site (IT-Lsn). The vineyard showed to act as a moderate carbon sink, with an average annual carbon uptake of 134 gC m^{-2}. However, the inter-annual variability of NEE was considerably high and environmental conditions during vine growing season showed to have a strong impact. The summer of 2014 was characterized by plenty of rainfall and the annual carbon uptake was the highest (207 gC m^{-2}). On the contrary, in 2015, several heat waves reached the area and the annual carbon uptake decreased to 69 gC m^{-2}. Our results show that perennial crops, if properly managed, have the potential to act as carbon sink on the medium-long term.

Multi-year regional terrestrial ecosystem carbon flux inferred from GOSAT XCO_2 data

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We infer regional monthly terrestrial ecosystem carbon flux from GOSAT XCO_2 data from 2010 to 2015, using the GEOS-Chem four-dimensional variational (4D-Var) data assimilation system and a global carbon data assimilation system (GCAS), respectively. GCAS is based on the global atmospheric chemistry model MOZART-4 and the local ensemble transform Kalman filter (LETKF). We use the GOSAT XCO_2 retrievals (version 7.3) produced by the NASA Atmospheric CO_2 Observations from Space (ACOS) project. The priori fluxes are the same as those used by CarbonTracker-2016. To examine the effect of using satellite observations, we also estimate regional fluxes using the combination of GOSAT XCO_2 data and Globalview ground flask CO_2 observations. We evaluate the inversion results with ground observations from Globalview and TCCON. The inverted fluxes from two inverse modeling systems are compared to investigate the impact of using different assimilation techniques. We also compare our inversion results with CT-2016. We focus on the inverted flux of the TRANSCOM regions such as Europe, boreal Eurasia and Amazon, where the validity of inverted fluxes from satellite observations is still in intense debate.

Water limitation can negate the effect of higher temperatures on the carbon sequestration potential of Swedish forests

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Boreal forests are important global carbon stocks and sinks and they play a fundamental role in climate change mitigation by storing and sequestering carbon and contributing to the production of renewable energy and materials. Boreal forests are also expected to be particularly vulnerable to climate change due to the rate of change projected at higher latitudes. One of the main potential threats in the boreal region is a decline of forest growth caused by water stress and thereby a decrease of forest carbon stocks and sinks. In

Sweden, it is generally expected that forest growth will be positively affected by higher temperature and longer growing seasons. However, several studies show that water availability already limits forest growth in southern Sweden. In addition, future climate scenarios project drier summers in the south increasing the risk of water stress and of negative consequences on forest growth. To investigate the effect of climate change on forest carbon under current management practices, we applied the dynamic forest ecosystem model ForSAFE to simulate the response of tree and soil carbon pools at 540 sites in Sweden. The study focuses on the effect of future precipitation regimes on the forest water and carbon balances. It illustrates how changes in soil moisture caused by climate change could affect forest growth and thereby tree and soil carbon pools in different regions in Sweden. The results show that the future forest carbon stocks will be strongly influenced by summer precipitation regimes and that drier conditions during the growing season will negatively affect carbon stocks in southern Sweden. The results also suggest that current forest management will need to be adapted regionally to cope with water availability changes and therefore maintain the mitigation potential of Swedish forests in the future.

Oral Presentations for Session 10: Decadal variability in biogeochemical cycles

Conveners: Ute Schuster, Frank Berninger

High-frequency measurements over long time periods allows separation of short-term variation from long-term trend. But understanding of slow processes is needed to define whether the observed long-term trend is actually part of slow variation. Decadal variability is studied in oceans, where it is related e.g. to carbon and heat budget, but also in ecosystems where multidecadal variability affects e.g. tree growth. This session considers long-term variation that is related to carbon and GHG cycles in different domains, such as oceans and ecosystems.

Carryover impacts on Net Ecosystem Productivity in a temperate mixed forest.

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A better understanding of the mechanism controlling the inter-annual variability of net CO2 ecosystem productivity (NEP) is needed and long term carbon exchange follow-ups are now more and more available at flux tower sites. Here we present twenty years of NEP estimations obtained using eddy covariance in a mixed forest at the Vielsalm station, in the Belgian Ardennes.

Even if the site heterogeneity and the set-up changes engendered large uncertainties on NEP, questioning the total carbon budget relevance, robust inter-annual anomalies were obtained (range: -206 – +123 gC m -2 yr-1, standard deviation: 93 gC m -2 yr-1) that allowed an inter-annual variability analysis to be made.

This analysis shows that the main causes of NEP inter-annual variability at the Vielsalm station were multiple but the most prominent feature was the robust lagged correlation observed between NEP anomalies and mean vapor pressure deficit during the preceding vegetation season, suggesting a carryover of water limitation during the previous year on NEP. Mechanisms driving this carryover are supposedly linked to tree physiology, which is confirmed by a dependency of canopy photosynthetic capacity to previous year water limitation. Some hypotheses, involving biomass allocation and bud formation, are proposed to explain its lagged impact on canopy photosynthetic capacity.

Other causes of NEP inter-annual variability were the radiation during the current vegetation season and the temperature at the end of the winter. Overall, the photosynthetic capacity combined with these two factors explained about 75 % of NEP inter-annual variability.

Twenty years of evapotranspiration measurement over a sub-alpine coniferous forest in Switzerland

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Forest ecosystems play a major role in the global cycles of carbon, water and energy. Evapotranspiration (ET), the sum of evaporation and vegetation transpiration, is a major component of the water cycle, and is strongly coupled with plants' physiological response to the environment. Here, we present twenty years of evapotranspiration data from the ICOS Candidate Class 1 Ecosystem Station Davos-Seehornwald (CH-DAV), located in a sub-alpine coniferous forest dominated by spruce in the Swiss Alps. The dataset presented here is among the longest set of continuous measurements of eddy covariance ecosystem water vapor fluxes (measurements since 1997) and therefore allows detailed analyses of the variability of water vapor fluxes over the past two decades, and potential trends in ecosystem functioning.

Based on the measurements of water exchange above the canopy, i.e. flux of H2O vapor, we observed more than two fold variations (decrease) in cumulative ET over the past 20 years. Such a magnitude of change can be debated given the limited variability in the supply of energy required for evaporation. On the other hand, ET is tightly coupled to plant development and productivity at different stages of growth. We therefore explore two different domains to understand the decadal variations in ET measurements: 1) in a data-driven approach, we test the sensitivity of annual cumulative ET to different gap-filling and data selection approaches, 2) and in an ecophysiological approach, we use concurrent measurements of tree sap flow and net ecosystem productivity to describe these significantly large variations.

Comparison of the impacts of acid and nitrogen additions on carbon fluxes in European conifer and broadleaf forests

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Increased reactive nitrogen (N) loadings to terrestrial ecosystems are believed to have positive effects on ecosystem carbon (C) sequestration. Global "hot spots" of N deposition are often associated with currently or formerly high deposition of sulphur (S); C fluxes in these regions might therefore not be responding solely to N loading, and could be undergoing transient change as S inputs change. In a four-year, two-forest stand (mature Norway spruce and European beech) replicated field experiment involving acidity manipulation (sulphuric acid addition), N addition (NH4NO3) and combined treatments, we tested the extent to which altered soil solution acidity or/and soil N availability affected the concentration of soil dissolved organic carbon (DOC), soil respiration (Rs), microbial community characteristics (respiration, biomass, fungi and bacteria abundances) and enzyme activity. We demonstrated a large and consistent suppression of soil water DOC concentration driven by chemical changes associated with increased hydrogen ion concentrations under acid treatments, independent of forest type. Soil respiration was suppressed by sulphuric acid addition in the spruce forest, accompanied by reduced microbial biomass, increased fungal:bacterial ratios and increased C to N enzyme ratios. We did not observe equivalent effects of sulphuric acid treatments on Rs in the beech forest, where microbial activity appeared to be more tightly linked to N acquisition. The only changes in C cycling following N addition were increased C to N enzyme ratios, with no impact on C fluxes (either Rs or DOC). We conclude that C accumulation previously attributed solely to N deposition could be partly attributable to their simultaneous acidification.

Carbon Observations at an Arctic Coastal site

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The highest amplitudes of Greenhouse gas concentrations are found in the Arctic and the concentration is still increasing. Furthermore, the winter-summer-amplitude of CO_2 is also larger in the Arctic. The concentration of CH_4 is increasing even faster than CO_2. It is known that the marine area is taking up a large fraction of the atmospheric CO_2 and new studies suggests that CH_4 is produced below the sea ice and can be emitted from the ice covered ocean through leads and during sea ice melts. This means that the sea ice cover affects the development of the concentration levels of CO_2 and CH_4. The aim of our project is to enhance the understanding of the local and regional processes controlling the climate changes in the Arctic, and to contribute to a qualified assessment of future climate changes and consequences. As a part of the project, we also study the distribution of the sea ice and we aim to contribute to the knowledge of the interaction between variation in greenhouse gases and the sea ice distribution. As a part of or the measurement-study, the goal is to estimate to which extent the distribution of the sea ice is affecting the development of the greenhouse gas concentration in the Arctic. At our new “pending” Arctic ICOS station we follow the development of the greenhouse gases CH_4 and CO_2 in the atmosphere at Station Nord in Greenland, which is situated on the edge to the Arctic Ocean. CO_2 concentrations from 2015 to 2018 are analysed and the first data suggest that CO_2 concentrations are related to wind directions. The measurements showed a large variation in the molar density in air from all directions, though dominatingly from North East and South West. However, the lowest concentrations are found in the south westerly winds.

Interannual drivers of the seasonal cycle of CO_2 in the Southern Ocean

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Resolving and understanding the drivers of variability of CO_2 in the Southern Ocean and its potential climate feedback is one of the major scientific challenges of the ocean-climate community. We use a regional approach on empirical estimates of pCO_2 to understand the role that seasonal variability has on long term CO_2 changes in the Southern Ocean. We use an ensemble of three machine-learning products: Support Vector Regression (SVR) and Random Forest Regression (RFR) from Gregor et al. (2017), and the SOM-FFN method from Landschützer et al. (2016). The interpolated estimates of ΔpCO_2 are separated into nine regions in the Southern Ocean defined by basin and biomes (defined by Fay and McKinley, 2014). The regional breakdown of the data highlighted the seasonal decoupling of the modes for summer and winter interannual variability. Winter interannual variability had a longer mode of variability compared to summer, which varied on a 4–6 year time scale. We separate the analysis of the ΔpCO_2 and its drivers into summer and winter. We find that understanding the variability of ΔpCO_2 and its drivers on shorter time scales is critical to resolving the long-term variability of ΔpCO_2. Results show that ΔpCO_2 is rarely driven by thermodynamics during winter, but rather by mixing and stratification due to the stronger correlation of ΔpCO_2 variability with mixed layer depth. Summer pCO_2 variability is consistent with chlorophyll-a variability, where higher concentrations of chlorophyll-a correspond with lower pCO_2 concentrations. In summary we propose that sub-decadal variability is explained by summer drivers, while winter variability contributes to the long-term changes associated with the SAM. This approach is a useful framework to assess the drivers of ΔpCO_2 but would greatly benefit from improved estimates of ΔpCO_2 and a longer time series.

Posters for Session 10: Decadal variability in biogeochemical cycles

Long-term soil CO_2 efflux measurements in a Norway spruce forest: DOY as variable to improve model of soil emissions

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Automated soil CO_2 efflux chamber measurements were carried out over a period of eight years in a young Norway spruce forest in the northeast region of the Czech Republic to determine seasonal and inter-annual variables affecting this flux. The data obtained was analysed with the aims of estimating long-term carbon losses from the soil and comparing selected models to determine the model best describing soil CO_2 efflux. The total amount of carbon released from the soil into the atmosphere per season varied from 6.4 to 11.2 tC ha−1 over the eight-year record. Our results show that seasonal variation in soil CO_2 efflux was driven mainly by soil temperature, while inter-annual variation showed the closest relationship with precipitation. One of the variables used in the CO_2 efflux models, beside environmental variables, was day of year (DOY). Incorporating this variable into models improved the estimation of soil CO_2 efflux dynamics. Therefore, we assume that models incorporating DOY could be used effectively to gap-fill measured soil chamber data. These models could also be appropriate for filling longer gaps on a scale from days to weeks, because DOY, as a single parameter, covers up to 80% of variability in the data. This study also demonstrated the different levels of correlation between investigated climate variables and soil CO_2 efflux at seasonal and inter-annual time scales. This highlights the importance of different environmental variables in interpreting long-term soil CO_2 efflux data and also modelling the complexity of the processes connected with soil CO_2 efflux in Norway spruce forest.

Acknowledgment: This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic within the National Sustainability Programme I (NPU I), grant number LO1415 and Completion of the research infrastructure CzeCOS to increase international quality of research of the global climate change impacts CZ.02.1.01/0.0/0.0/16_013/0001609.

Inter-annual variability of carbon fluxes at the FR-Gri ICOS crop site as influenced by meteorology and management.

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In agricultural ecosystems, both meteorological drivers and crop management activities affect carbon dioxide (CO_2) and greenhouse gas (GHG) exchanges, and potentially large inter-annual variability in these fluxes can be observed. This study presents the carbon (C) and GHG balance of the FR-Gri ICOS site from 2005 to 2017, and investigates the role of meteorological drivers and crop management activities to explain inter-annual variability in the exchanges of CO_2, N_2O and CH_4 fluxes.

The observation site, located 40 km to the west of Paris (France) on a fairly flat plateau, is a wheat-barley-maize rotation with the introduction of rapeseed in 2012. The site receives large amounts of organic fertilisation, but behaves as a strong C source to the atmosphere, especially owing to the increase in crop residue exportations during the observation period. The exportations have increased from around 4 to around 8 t C ha^{-1} $year^{-1}$ over the period, on average, except for maize for which it remained constant. In the meantime, the carbon importations have increased from around 1 to around 2 t C ha^{-1} $year^{-1}$ during the same period. Overall the field lost around 2 t C ha^{-1} $year^{-1}$ over the whole period but this loss was largely driven by the last years (2012-2017). This loss would represent almost 20 % of the soil total C content in the 0-60 cm horizon, as measured in 2005.

The discussion particularly focuses on the inter-annual variability of the C fluxes and on the large observed carbon losses, searching for relationships with meteorological variables and crop management activities. Special attention is also given to the quantification of uncertainties and possible drawbacks in the methodology. Finally, the effect of the winter intermediate (cover) crops on the C balance is also discussed.

Long-term assessment of croplands carbon budgets: Effects of climate and management in Southwestern France

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This study presents a net CO2 flux and carbon budget analysis over 10-years for two cropland sites located in South-West France (Béziat et al., [1]). Both currently belong to the ICOS ERIC. They benefit from similar climatic conditions but contrasted management regimes and different crop rotations representative of the region (winter wheat/irrigated maize for silage at Lamasquère, winter wheat/rapeseed/winter wheat/sunflower at Auradé). Continuous eddy-covariance measurements and regular biomass samplings were performed in order to obtain the daily and annual Net Ecosystem Exchange (NEE) as well as the annual

Net Biome Production (NBP). Effects on NBP of straw management, cover crops (white mustard, or spontaneous regrowth), organic vs mineral fertilization were analyzed. Annual carbon budgets ranged from -365 g C-eq/m2 (C sink) to 558 g C-eq/m2 (C source). Even if winter crops were generally C sinks and summer crops behaved as C sources, dry and warm spring conditions could switch a winter crop into a carbon source which is a matter of strong concern in a context of climate change. Moreover, crop management had a major influence on carbon budgets at different time scales (seasonal, annual or pluri-annual) and we could identify that straw burial, organic fertilisation and cover crops should be encouraged in our area. Indeed, straw management was the main driver of NBP and carbon input through organic fertilisation could be as large as the annual NEE. Also, the white-mustard cover crop at Lamasquère (in 2013) allowed a net CO2 fixation of 63 g C-eq.m-2, corresponding to 20% of the annual NEE that year (-332 g C-eq.m-2). We conclude that long term monitoring of net CO2 fluxes at cropland sites are critical for identifiying the best strategies for increasing cropland soil C stocks (contributing to the 4/1000 initiative) and fight against climate change.

Trends and anomalies in over twenty years of flux observations in the mid-latitude Scots Pine forest Loobos

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The Loobos tower flux station (52° 09' 59.34" N, 5° 44' 36.79" E, 25 m a.s.l.) was established in 1995 in a Pine forest (89% Pinus sylvestris) on sandy soil in the Netherlands. The forest was planted around 1910 to prevent sand storms and to provide wood for use in coal mines. Since 1996 the tower has been measuring the fluxes of CO2, water and heat almost continuously, alongside with radiation, air and soil temperatures, humidity, soil moisture. With 20+ years of data, our record is one of the longest worldwide. Funding for 10 more years has now been guaranteed.

We present a meta-analysis on the use of the Loobos site and data over these 20 years in its European and international context as well as the main trends in ecosystem, climate and fluxes. Over the years there has been a steady encroachment of Prunus serotina. We also survey what these single-site data are telling us about the (apparent lack of) sensitivity of the forest's carbon balance to external disturbances, such as droughts, temperature, gales and anomalies in winter and summer. We will compare the flux time series with tree ring and sap flow data.

Global indicators of ocean carbon uptake: a pilot study

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Understanding the global ocean carbon sink is of key importance for understanding future climate change due to human CO2 emissions. Key research questions include how much CO2 is taken up by the ocean and on which time scales the ocean sink adapts and changes. Annual syntheses of the Global Carbon Budget utilize several observation- and model-based products for air-sea CO2 fluxes. What these products have in common is that the underlying methods are quite complex and based on e.g. neural network theories or mathematical gap filling. Here we evaluate how much information about the changes in ocean carbon

uptake over the past five decades can be attained from basic statistical analyses of the observational data. We use the Surface Ocean CO2 Atlas (SOCAT), which now includes 18.5 million surface ocean carbon dioxide fugacity (fCO2) measurements globally, spanning the years 1957-2014 (v4). When plotted as frequency distributions these data, globally, show a clear shift towards higher values decade by decade between 1970 and 2014. This shift alligns with the decadal increase in atmospheric CO2. Using the observed fCO2 we have calculated the air-sea CO2 flux, identified a decadal shift in the frequency distribution and quantified how much of this shift is due to the change in the air-sea CO2 disequilibrium and how much is due to changes in transfer velocity. The frequency plots, and the quantified change in the distribution have then been compared to air-sea CO2 flux products from the Surface Ocean CO2 Mapping intercomparison (SOCOM). This allows for assessment of how much added value the flux products provides compared to observations alone. To quantify the bias introduced by spatial heterogenity in the observations, we have compared the shift in the observations with that simulated by CMIP5 observations, using both the full and subsampled model fields to match the spatial

CO_2 uptake and ocean acidification in the North Atlantic and Southern Indian Oceans over the last two decades

Leseurre Coraline, LOCEAN, Univ. Paris 6, Paris, France, presented by Claire Lo Monaco

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The North Atlantic and Southern Oceans are two major CO_2 sink regions. Because pH is naturally low at high latitudes, the increase in oceanic CO_2 raises particular concerns in these regions where surface waters could become undersaturated with respect to calcium carbonate before the end of the century. We used repeated observations collected over the last two decades to investigate the evolution of CO_2 uptake and ocean acidification in the North Atlantic Subtropical Gyre (50°N-63°N) and in the Southern Indian Ocean (45°S-57°S). Our results show an increase in the fugacity of CO_2 (fCO_2) in surface waters during summer that is generally close to the increase in the atmosphere (between +1.6 µatm/yr and +2.4 µatm/yr), and associated with a decrease in pH ranging from -0.0012/yr to -0.0027/yr. Larger changes were found in highly productive waters in the vicinity of Crozet and Kerguelen Islands for both fCO_2 (between +3.3 µatm/yr and +5 µatm/yr) and pH (between -0.0028/yr and -0.0065/yr). As a consequence, undersaturation of these waters with respect to aragonite and calcite could be reached in 2054 and 2070, respectively. For all regions, the trends observed during summer are mainly driven by an increase in Dissolved Inorganic Carbon (DIC). On the contrary, data collected during winter in the North Atlantic Subtropical Gyre show a significant cooling in surface waters that slowed down the trends in fCO_2 and pH (+1.0 µatm/yr and -0.0012/yr, respectively over the period 2001-2017). In this region we also found a reversal of the trends in recent years (2005-2017), i.e., fCO_2 decreased (-0.7 µatm/yr during winter and -1.1 µatm/yr during summer) and pH increased (+0.0005/yr during winter and +0.0013/yr during summer). These recent changes are explained by a reduced trend in DIC during winter and the cooling of surface waters and increased alkalinity during summer.

Oral Presentations for Session 11: The identity and societal impact of a researcher within ICOS

Communicating climate science to non-scientific audience through social media – Case ICOScapes

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Communicating scientific topics to general, non-scientific audience can be challenging for many reasons. It is a skill to popularise science so that it can be understood by anybody while still being factually correct. Additionally, communicating about scientific projects while they are still in progress requires particular attention in order to balance between communicating too much before the results are final, or too little which leads to non-interested audience.

Social media, i.e. channels such as Instagram, Twitter and YouTube, offer ways for two-way communications with large audience almost unlike any other traditional or online channel. The challenge is, of course, to reach a large audience in the competitive media landscape.

ICOS Integrated Carbon Observation System decided to take on this challenge and created a social media campaign to communicate its efforts to measure and observe greenhouse gases across Europe and beyond. The campaign consists of beautiful nature photographs and of short videos including station crew interviews, which are then published in several social media channels together with ICOS key messages about the work. A professional photographer, which already was well known in social media, was enlisted to travel around the stations and take photographs for this purpose, while the videos were taken and produced by in-house staff.

The campaign has now been going on some 8 months. The results are very good indeed, both in terms of raising external awareness and also in terms of improving internal engagement and coherence of the community. To conclude, social media can work well as a communications channel, engaging audience, if the communicating organisation is able to allocate resources for the campaign and adapt to as well as utilise the conventions of the social media channels selected for the campaign.

What is an ICOS identity? An investigation into the internally perceived identities of ICOS RI

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ICOS RI (Integrated Carbon Observation System Research Infrastructure) is a distributed research infrastructure that has operational nodes in several countries. This is, at times, challenging in terms of communication, accessing information flows and understanding the level of commitment and motivation of diverse types of internal member groups.

Due to the infrastructure being built on several types of organisations, consisting of institutes of different agendas and histories, the perceived purpose of ICOS RI, the motivation to be part of ICOS RI, and the expectations from it vary. For this reason, it is vital to establish a wider understanding of these issues to be able to further facilitate community building within the infrastructure, and to enable the maintenance of an inclusive culture where fostering the 'sense of ICOS community' would be possible in the long term.

This study investigates the internal ICOS RI members' perceptions of the purpose of ICOS, their motivations to be part of ICOS RI and their expectations from it. The focus is on three temporal perspectives: past, present and future. The study shows that there are several different types of internally perceived identities of ICOS RI and analyses how they differ inside the infrastructure by applying theoretical and methodological approaches around the 'Sense of Place' -concept.

Oral Presentations for Session 13: Bridging the gap between bottom-up and top-down methods

Conveners: Dominik Brunner

This session focuses on emission estimates based on two complementing methodologies, the so-called bottom-up and top-down approaches. Topics include advances and approaches to reduce estimate uncertainties. Atmospheric verification of emissions is vital along with global inversion methods. Results improving the current understanding of northern terrestrial land sinks, that are based on accurate in situ measurements or results showing changes in natural or anthropogenic emission are highly welcome.

Quantifying methane emissions from coal mining shafts in Silesia, Poland

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The methane emissions from coal mining in the upper Silesia area in Poland were estimated from bottom-up studies to be ~1.7% of Europe's total methane emissions, which are vented to the atmosphere from a relatively small number of large coal mining shafts. However, the reported emission rates may be associated with large uncertainties. We have used a recently developed active AirCore system on an Unmanned Aerial Vehicle (UAV) to sample the plumes from the coal mining shafts to validate the emission rates of these large emitters and to develop methodologies to quantify point source CH_4 emissions. The UAV AirCore system is designed to continuously collect air samples during flight, which are later analysed to retrieve the profiles of CH_4, CO_2, and CO. In a field campaign during the period 14 - 23 August 2017, mole fraction measurements of CO_2, CH_4, and CO downwind the venting shaft of a large coal mining facility (Pniowek V) were made during 18 flights. Radiosonde launches prior to and during the flights provided wind speed and wind direction profile measurements. We used a mass balance approach and a Gaussian plume model to estimate the emissions rate. For the latter, the dispersion parameters were optimised by the profile measurements. We compare our Gaussian plume estimate with that of a mass balance approach, and compare our constrained plume size with that of the Briggs model at a similar distance, wind speed, and temperature. Besides these, all the AirCore samples were also collected into multi-layer foil bags, and later analysed for ^{13}C and deuterium in CH_4. Furthermore, we will present the results of sampling multiple coal mining shafts in the upcoming campaign in May/June 2018. This study shows the versatility of the Active AirCore system, and demonstrates its potential to quantify point source emissions.

CarboScope decadal inversions of NEE over Europe at regional scale: towards a pre-operational system

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With an increasing network of atmospheric stations that produce a constant data stream, top-down inverse transport modelling of GHGs in a quasi-operational way becomes feasible. Within the H2020 project VERIFY such a pre-operational system is being set up to infer net ecosystem exchange based on the CarboScope regional inversion system. This embeds the regional inversion, consisting of mesoscale transport from STILT, prior fluxes from the diagnostic VPRM biosphere model, and emissions from the combination of EDGAR v4.3 with the annually updated BP emissions, within a global inversion using the two-step approach. As a first step, the protocol of the EUROCOM inversion intercomparison was adopted, using observations from more than 20 stations covering the 2006-2015 time period. The domain covers most of Europe (33 – 73N, 15W – 35E) with a spatial resolution of 0.25 deg. for fluxes and 0.5 deg. for flux corrections inferred by the inversion. Different prior uncertainty structures (spatial correlation scales) are used to assess their impact on retrieved fluxes. Also the impact of gaps in atmospheric observations on fluxes is investigated. Results are presented with posterior uncertainties at national scales on annual and monthly temporal scales. An outlook will be given as to the further development with respect to utilization of night-time data from tall towers to separately constrain photosynthesis and respiration, and with respect to using different fossil fuel emission inventories.

Quantifying the UK's carbon flux: a hierarchical Bayesian inversion approach using a national tall tower measurement network and comparing the use of two biosphere models as prior information

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The UK has committed to an 80% reduction in greenhouse gas (GHG) emissions from 1990 levels by 2050 to help curb dangerous global climate change. In light of this commitment, a dense network of measurement sites has been set up around the country to monitor concentrations of GHGs in the atmosphere.

We explore the potential of this network to estimate the UK's carbon fluxes with a top-down atmospheric inversion approach, using bottom-up inventories that have not previously been applied to these problems. Due to the difficulties in separating fluxes of anthropogenic and biospheric origin, and the relative higher uncertainties in prior biospheric flux estimates, we focus on determining the UK's net biosphere flux.

We present a hierarchical Bayesian inverse modelling framework combined with the Lagrangian atmospheric dispersion model, NAME, developed by the UK Met Office. Prior biospheric fluxes are separated into gross primary productivity and total respiration components and are provided by two different biosphere models, JULES and CARDAMOM, at high temporal resolution.

Despite some notable differences between the two priors, posterior flux estimates appear to converge on a similar seasonal cycle and annual net flux. Using the JULES (CARDAMOM) prior we find UK estimates for the net CO_2 sink in June 2014 of – 528 ± 100 Tg(CO_2) yr^{-1} (– 402 ± 112 Tg(CO_2) yr^{-1}), net CO_2 source in December 2014 of 242 ± 98 Tg(CO_2) yr^{-1} (259 ± 125 Tg(CO_2) yr^{-1}) and annual net biospheric CO_2 flux of – 33 ± 83 Tg(CO_2) yr^{-1} in 2014 (10 ± 89 Tg(CO_2) yr^{-1}). Both biosphere models tend to overestimate the summer CO_2 sink, which suggests they may be missing some processes such as the effect of crop harvest.

Airborne in-situ sampling over Europe during CoMet

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During May and June 2018, a large campaign aimed at atmospheric measurements of greenhouse gases over Europe called CoMet (Carbon Dioxide and Methane Mission) has taken place. Within CoMet we used the German research aircraft HALO, equipped with in-situ and remote sensing instrumentation, for characterisation of the CH_4 and CO_2 distribution over Europe, including the signature of larger point sources located throughout the continent. The main aims are the validation of onboard remote sensing as well as satellite borne remote sensing against the in-situ measurements traceable to WMO scales. A further objective the provision of data for validation of atmospheric transport models such as used in global and regional inversions.

On HALO, continuous in-situ measurements of CO_2, CH_4, CO and H_2O were performed with the use of a modified CRDS instrument dubbed JIG (Jena Instrument for Greenhouse gas observations). Additionally, a large set of discrete air samples was collected with JAS, the Jena Air Sampler, for laboratory analyses of CO_2, CH_4, N_2O, CO, SF_6, H_2, as well as isotopes ^{13}C in CO_2, ^{18}O in CO_2, ^{13}C and ^{2}H in CH_4 throughout the atmosphere over points of interest.

This presentation will discuss the initial results of the observations obtained with JIG and JAS instruments during the CoMet mission, many of which were collected during vertical profiles over ICOS atmosphere stations. Comparison between the forecasted CO_2 and CH_4 fields will also be discussed using products generated with CAMS (Copernicus), high-resolution WRF-GHG (MPI-BGC) and MECOn (DLR) modelling frameworks. A sensitivity analysis, including the impact resulting from utilising different emission inventories, is also envisaged.

Posters for Session 13: Bridging the gap between bottom-up and top-down methods

Inverse Modelling of Swiss CH4 and N2O Emissions

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Globally, emissions of long-lived non-CO2 greenhouse gases (GHG) account for approximately 30% of the radiative forcing of all anthropogenic GHG emissions. On the country level, 'bottom-up' estimates of non-CO2 GHG emissions are often connected with relatively large uncertainties when compared with those of CO2. The Swiss national inventory report (NIR) states an uncertainty of 39% and 18% for N2O and CH4 emissions, respectively, whereas that of anthropogenic CO2 is only 0.7%. To further constrain these emissions, 'top-down' methods using atmospheric observations and inverse modelling can be employed as an additional and independent source of information.

Here, we present regional-scale atmospheric inversions for CH4 and N2O emissions in Switzerland, making use of observations at Beromünster and Laegern-Hochwacht on the Swiss Plateau and two neighbouring mountain-top sites. Continuous CH4 observations are available from all sites since 2013, whereas continuous observations of N2O commenced at Beromünster in January 2017. We use the Lagrangian particle dispersion model FLEXPART-COSMO at high resolution (7 x 7 km2) in connection with two different inversion systems to estimate spatially and temporally resolved emissions. In general, we find good agreement of the total Swiss CH4 emissions between our top-down estimate and the NIR reporting. In addition, a pronounced seasonality with reduced winter time emissions can be seen in all years, which is most likely related to reduced emissions from manure handling at lower temperatures. We observe that uncertainties in the model's boundary conditions can induce large offsets in the national total emissions whereas the spatial patterns are less sensitive. For N2O, we present first preliminary results using an inversion approach with fewer spatial but more temporal degrees of freedom to account for the large temporal variability of the emissions. As for CH4, total Swiss emissions are compared to the NIR estimates.

Quantifying the natural production rate of radiocarbon using stratospheric $^{14}CO_2$ measurements

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Radiocarbon (^{14}C) plays an important role in the carbon cycle studies to understand both natural and anthropogenic carbon fluxes, but also in atmospheric chemistry to constrain hydroxyl radical (OH) concentrations in the atmosphere. Radiocarbon is primarily produced in the upper atmosphere due to reactions of nitrogen with thermal neutrons that are induced by cosmic radiation. ^{14}C is quickly oxidized to ^{14}CO, which is then further oxidized to $^{14}CO_2$ by OH. To this end, better understanding the radiocarbon source is very useful to advance the use of radiocarbon for these applications. However, upper atmospheric ^{14}C observations have been very sparse to constrain the magnitude and the location of the ^{14}C production as well as the transport of radiocarbon from the stratosphere to the troposphere.

We show stratospheric $^{14}CO_2$ measurements that were obtained by analyzing air samples from AirCore flights in 2014 and from a recently developed lightweight stratospheric air sampler (LISA) in 2018 in Sodankylä, Finland (~ 67°N), and from the Geophysica flights over Greece (~ 34°N) in 2016. We estimate the production rates of radiocarbon based on the correlation between $^{14}CO_2$ and N_2O, and the estimated N_2O loss rate using the new ^{14}C datasets. We report the variabilities of the estimated ^{14}C production rates and compare them with those from model simulations. Furthermore, we evaluate different cosmogenic ^{14}C production scenarios using the observed vertical profiles of ^{14}C.

Preliminary results of ground - based column greenhouse gases retrieval using FTIR spectroscopy, influence of the temperature profiles in the forward model

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Retrievals of column abundances of dry-air mole fraction of carbon dioxide were used from a low spectral resolution (0.5cm-1) tabletop FTIR system, EM27, by analysing direct solar radiation [1][2]. Retrieval of the atmospheric column greenhouse gases uses a-priori profiles of the interested species and pressure and temperature profiles, used in the forward model of the processing. Here, the results are compared using pressure and temperature profiles obtained from model and compared with the temperature and pressure profiles obtained from a collocated microwave radiometer.

This paper presents retrievals from EM27 system during summertime of 2017 and 2018 over Magurele (44.35N, 26.03E), a peri-urban area, and approximately 10 km south of Bucharest. Measurements are compared with satellite retrievals from IASI (Infrared Atmospheric Sounding Interferometer) and OCO-2 (Orbiting Carbon Observatory). Possibility of using microwave radiometer temperature profiles for the ground – based retrieval algorithm is also explored. The influence of the temperature profiles introduced in the forward model of the FTIR processing is analysed and then compared with satellite retrievals. Satellite data were selected by defining an area of approximately 50 km around the ground based system in cloud free conditions. Comparison with ground based measurements are made within a ± 1 hour from the satellite overpass the ground based location.

The study will assess the improvement the retrieval of greenhouse gases of this system which can be also suitable as a validation tool of ESA's Sentinel 5 Precursor, as it covers the same spectral region as used by the infrared channel of the TROPOMI (TROPOspheric Monitoring Instrument).

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The impact of an imperfect anthropogenic prior knowledge at KIT ICOS-D atmospheric station in regional CO2 inversions

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As the observational atmospheric network within ICOS is increasing, inverse estimation of surface-atmosphere exchange fluxes of CO2 at regional scales becomes feasible. It is typically assumed in inversions that CO2 emissions from fossil fuel combustion are well known, much better than fluxes related to biosphere-atmosphere exchange. However, with increasing spatial and temporal resolution of the transport models (and thus of the flux fields), the uncertainties in fossil fuel emissions also increase. Due to the fact of the high concentration of industrial centres in Germany the ICOS-D atmospheric observation station KIT / Karlsruhe is surrounded in the near and middle distance range with stronger CO2 anthropogenic emissions point sources like coal power plants and bigger manufactories. The consequence is that inaccuracies in the contribution from emissions in the vicinity of atmospheric stations can lead to erroneous biosphere-atmosphere exchange fluxes obtained from regional inversions.

Thus for inversions to be successful at regional scales it becomes a necessity to take into account the uncertainties in fossil fuel emissions. We introduce a fossil fuel emission impact filter technique for STILT (Stochastic Time-Inverted Lagrangian Transport) using IER/EDGAR4.3 emission inventory at high resolution of 1 x 1 km to improve the model-data representation at the KIT/ Karlsruhe atmospheric site in regional inversions.

First eddy covariance flux analysis at the tall tower site Beromünster, Switzerland

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Trace gas measurements at the tall tower site Beromünster, Switzerland are being made since the year 2012. Attempts to calculate CO2 and H2O fluxes from the height dependent concentration measurements were limited by the fact that neither the advective nor the turbulent flux were available [Satar et al., 2016]. Here we present an update of flux estimates including Eddy covariance analysis at the top inlet of the tall tower. We show that the rather long transfer time from the inlet to the detector of roughly one minute has no obvious negative effects on the quality of the flux data. We also document that due to the height of 212 meters of Beromünster's uppermost tower inlet, the data sampling rate can be reduced safely to a few seconds with no loss of information compared to small eddy flux towers, where a significantly higher frequency is required. We will discuss variations of the CO2 and H2O fluxes as well as the annually integrated fluxes, and the water use efficency over the year. In the near future, a high precision oxygen analyzer will be placed at the site to investigate the interaction between the atmosphere and the biosphere further.

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Synthesising terrestrial and atmospheric models and data into national-scale estimates of UK nitrous oxide emissions

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National-scale emissions of nitrous oxide are calculated as the product of the fertiliser nitrogen applied annually and the fraction of this which is emitted as N2O. The latter term, the emission factor, is estimated on a small scale, from static chamber measurements following fertiliser application. However, there are large uncertainties in extrapolating these heterogeneous obervations to cumulative annual totals at the field-scale. In a top-down approach, large-scale fluxes can be estimated by inverse modelling of the atmospheric mass balance, using observations of the mixing ratio in the well-mixed boundary layer.

Here, we assimilate data from both these approaches in a Bayesian framework, to provide the best estimate of the national-scale emissions with well-defined uncertainties. To do this, we use an emulator of process-based model behaviour, which retains the simplicity of an empirical model, and can easily be related to the IPCC Tier 1 model. In the Bayesian calibration of this model, we incorporate a large set of data collected using the static chamber method, including the effects of temperature and soil moisture. We account for the errors which arise in the upscaling process, when grid cell averages are used as inputs to nonlinear processes. We then incorporate estimates of the large-scale emissions inversely inferred from measurements of the atmospheric mixing ratio of N2O on a tall-tower network. This involves quantifying the footprint of each tower at each time step. The parameters of the emulator model are then varied in an MCMC algorithm which assesses their likelihood, based on the discrepancy between fluxes predicted by the emulator and those inversely inferred from the atmospheric mass balance. This approach retains the simplicity of the Tier 1/2 models, but synthesises measurements at different scales to best constrain the national scale emissions.

Using long-term high precision isotope measurements to characterise sources of atmospheric methane at various European locations

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The increase of methane mole fraction is an important contributor to radiative forcing, and a major concern is to reduce uncertainties associated with the source strength and partitioning of this important greenhouse gas. Isotope analysis is a widely used technique for source characterization, but due to analytical challenges it has been difficult to obtain long-term high resolution time series that could help deciphering sources on hourly to daily timescales. At the same time, isotopic source signatures are not always well characterized and may vary in time and space, which is usually not taken into account in the analysis. Through long-term measurements of both ^{13}C and deuterium isotopic signatures in methane, we get a clearer knowledge of the actual methane sources influencing one region, as well as their temporal variations.

We report $\delta^{13}C$ and δD measurements that were performed in Lutjewad (North of the Nether- lands) during 5 continuous months in 2016 and 2017. Another high resolution time series is planned in the city of Krakow, Poland, during the summer 2018. The results from Lutjewad clearly illustrate a prevalence of biogenic sources, despite the presence of a nearby gas field and the offshore gas operations on the North Sea. In Krakow we aim to use the isotope data to better quantify the methane emission drivers in this city. The potential influence of the emissions from the nearby mining area of Silesia, which represents one the largest methane sources in Europe, will also be assessed.

This work is part of the Marie Sklodowska-Curie Initial Training Network MEMO², which will enable us to extend these measurements to other European locations in the coming years.

EUROCOM project: collaborative reanalysis of European CO2 fluxes over the period 2006-2015

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Terrestrial ecosystems play a dominant role in moderating the increase of atmospheric CO2 due to human activities. They are thought to absorb more than 1/4 of the anthropogenic CO2 emissions. Within the framework of the Paris agreement, several European countries have pledged to reduce their net CO2 emissions by increasing the carbon uptake by their terrestrial ecosystems. Yet, current bottom up estimates of the net ecosystem exchanges (NEE) differ significantly, which makes it very difficult to assess the reality of the countries commitments.

Atmospheric inversions can in theory provide a reliable estimate of the current NEE across Europe, which should help calibrating the bottom-up models. Yet, the current estimates from global coarse-grid inversions range from a small source to a sink of more than 1 PgC/yr during the previous decade. The origin of these discrepancies isn't entirely clear, as there are large differences in the inversion setups (different transport models, prior and observational constraints, different optimization algorithms).

The EUROCOM project aims at providing a robust top-down estimate of the European NEE and its uncertainty over the period 2006-2015. This is achieved through an international collaboration, involving researchers from seven European research institutes and the support from many data providers, who provide prior and non-optimized fluxes, and observations.

A common inversion protocol was proposed, defining a common selection of observation sites (primarily from the (pre-)ICOS network), a common fossil-fuel emissions dataset and a similar model grid. The inversions differ by their prior NEE (VPRM, LPJ-GUESS, SiBCASA and ORCHIDEE models were used), their transport models (FLEXPART, STILT, NAME, TM5 and CHIMERE), and by the inversion algorithms used (variational, EnKF and MCMC).

In this presentation we will provide an overview of the main outcomes of the intercomparison, and we will talk of the future of the collaboration, beyond the end of the project

Towards a data-driven estimate of northern wetland CH_4 emissions using artificial neural networks and a set of CH_4 flux sites

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During the last decade eddy covariance (EC) measurements of methane (CH_4) fluxes have become more common, mainly due to rapid instrument development. EC CH_4 fluxes have been at several wetland sites and some of these already have a decade long CH_4 flux time series available. This study aims to integrate these available data by using artificial neural networks (ANNs) to obtain a data-driven estimate of northern (north from 45° N) wetland CH_4 emissions. Such a product could be useful for process model performance evaluation. First we train an ANN model using the measured fluxes and driving variables and then use the model together with gridded data (e.g. WFDEI meteorological data (WATCH Forcing Data methodology applied to ERA-Interim data) and MODIS (Moderate Resolution Imaging Spectroradiometer) products) to achieve a data-driven estimate of northern wetland CH_4 emissions. Similar approaches have been previously used to approximate global CO_2 and H_2O fluxes, but not for wetland CH_4 emissions. First results show reasonable overall agreement between the ANN modelled CH_4 fluxes and independent validation data (Pearson correlation coefficient 0.66). This presentation summarises the initial results and compares them against process models including LPX-Bern-DYPTOP, discusses the limitations of the study and identifies the next steps.

Non-growing season methane emissions are a significant component of annual emissions across northern ecosystems

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Wetlands are the single largest natural source of atmospheric methane (CH_4), a greenhouse gas, and occur extensively in the northern hemisphere. Large discrepancies remain between “bottom-up” and “top-down” estimates of northern CH_4 emissions. To explore whether these discrepancies are due to poor

representation of non-growing season CH_4 emissions, we synthesized non-growing season and annual CH_4 flux measurements from temperate, boreal, and tundra wetlands and uplands. Median non-growing season wetland emissions ranged from 0.9 g m^{-2} in bogs to 5.2 g m^{-2} in marshes and were dependent on moisture, vegetation, and permafrost. Annual wetland emissions ranged from 0.9 g m^{-2} y^{-1} in tundra bogs to 78 g m^{-2} y^{-1} in temperate marshes. Uplands varied from CH_4 sinks to CH_4 sources with a median annual flux of 0.0 ± 0.2 g m^{-2} y^{-1}. The measured fraction of annual CH_4 emissions during the non-growing season (observed: 13 to 47%) was significantly larger than was predicted by two process-based model ensembles, especially between 40-60° N (modeled: 4 to 17%). Constraining the model ensembles with the measured non-growing fraction increased total non-growing season and annual CH_4 emissions. Using this constraint, the modeled non-growing season wetland CH_4 flux from >40° north was 6.1 ± 1.5 Tg y^{-1}, three times greater than the non-growing season emissions of the unconstrained model ensemble. The annual wetland CH_4 flux was 37 ± 7 Tg y^{-1} from the data-constrained model ensemble, 25% larger than the unconstrained ensemble. Considering non-growing season processes is critical for accurately estimating CH_4 emissions from high latitude ecosystems, and necessary for constraining the role of wetland emissions in a warming climate.

MEMO²: MEthane goes MObile – MEasurements and Modelling

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Reaching the target of the 2015 United Nations Climate Change Conference in Paris (COP21) - limiting global warming “well below” 2°C - requires massive reductions of greenhouse gas emissions, and achieving significant reduction of greenhouse gas emissions is a logical headline target of the EU climate action and of the H2020 strategy.

CH_4 emissions are a major contributor to Europe’s global warming impact and emissions are not well quantified yet. There are significant discrepancies between official inventories of emissions and estimates derived from direct atmospheric measurement. Effective emission reduction can only be achieved if sources are properly quantified, and mitigation efforts are verified. New advanced combinations of measurement and modelling are needed to archive such quantification.

MEMO² is a European Training Network with more than 20 collaborators from 7 countries. It is a 4-years project and will contribute to the targets of the EU with a focus on methane (CH_4). The project aims to bridge the gap between large-scale scientific estimates from in situ monitoring programs and the ‘bottom-up’ estimates of emissions from local sources that are used in the national reporting by I) developing new and advanced mobile methane (CH_4) measurements tools and networks, II) isotopic source identification, and III) modelling at different scales. MEMO² will facilitate intensive collaboration between the largely academic greenhouse gas monitoring community and non-academic partners who are responsible for evaluating and reporting greenhouse gas emissions to policy makers.

We will present the project and its objectives to the scientific community to foster collaboration and scientific exchange.

Linking photosynthesis F_{760} and PRI at daily to seasonal scales.

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Satellite derived Sun-induced fluorescence (SIF) has been proposed as a promising signal for an improved spatio-temporal monitoring of Gross Primary Production (GPP), as it is an energy dissipation mechanism linked to the photosynthetic process. However, recent publications show that F is mainly controlled by the Absorbed Photosynthetic Active Radiation (APAR) which is also the main driver for GPP. To fully use the potential of SIF as a robust estimator for photosynthesis and plant stress, it is crucial to understand if SIF can also be related to the photosynthetic light- and dark reactions (light use efficiency; LUE). Since satellite products are limited by the overflight time, spatial resolution and cloud cover, long term, continuous, in-situ measurements of F, GPP and APAR are needed.

In a 2-month long measurement campaign, carried out during the European heatwave of 2015, we used a spectrometer system (SIF-Sys) that measured in the 350- 1100 nm range, with high spectral resolution (FWHM: 1 nm) and a fast sampling frequency (6s). The measurements were carried out within a sugar beet field close to an eddy-covariance tower. This setup allowed tracking the diurnal and seasonal relationships between APAR, F and GPP as well as the photochemical reflectance index (PRI) under changing environmental conditions. We found that under drought conditions, the relationship between F760 and GPP is significantly reduced (from R2: 0.57 to 0.05). Even though APAR-independent fluorescence yield (FY760) showed a strong seasonal relationship (R2:0.78) with the LUE, this relationship seems to be controlled by phenological changes of the canopy over the growing season.

Using 6-year of SMOS soil moisture data in combination with CO2 flask samples to constrain terrestrial carbon fluxes with CCDAS

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The terrestrial carbon cycle is an important component of the global carbon budget because of its large sink and sensitivity to climate change. However, terrestrial biosphere models used for quantifying carbon fluxes have large uncertainties, which impacts global carbon budget assessments. The land surface carbon cycle is tightly coupled with the hydrological cycle through biological processes in plants. In this context, observations of soil moisture are expected to improve modeling of carbon fluxes in a model-data fusion framework. Here, we employ the Carbon Cycle Data Assimilation System (CCDAS) to assimilate a 6-year SMOS L3 surface soil moisture product in combination with in-situ measurements of atmospheric CO2 concentrations at global scale. We find that the assimilation of SMOS soil moisture improves simulated soil moisture in regions where the prior model simulation shows poor correlations with SMOS data, but slightly degrades the fit in regions where a strong correlation with the SMOS data is already obtained with the prior simulation. Atmospheric CO2 concentration are simulated well after the assimilation. Assimilation of SMOS soil moisture shows to be efficient in improving gross (GPP) and net (NEP) fluxes of CO2 at both site-scale and global scale when compared against independent estimates from atmospheric transport inversions and up-scaled eddy covariance measurements. Our model shows good agreement in the inter-annual variability of global NEP and GPP with these independent datasets, however, larger differences in modeling NEP and GPP are detected in tropical and subtropical regions when compared on smaller scales. In general, CCDAS obtains smaller annual mean NEP values than the atmospheric inversion and multiple Dynamic Global Vegetation Models (DGVMs), but larger GPP values than the upscaled eddy covariance dataset and the MODIS observations. This study demonstrates the high potential of long-term soil moisture in constraining the terrestrial carbon cycle.

Contribution of terrestrial carbon budget to atmospheric CO_2 in South Korea

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Atmospheric CO_2 concentration has been steadily increasing since pre-industrial times due to anthropogenic CO_2 emissions. A great uncertainty exists in the estimate of the contribution of terrestrial carbon budgets to the increasing atmospheric CO_2 at the national level. Here, we use tower observations of atmospheric CO_2 concentration and a trajectory model to investigate temporally resolved CO_2 fluxes in South Korea. From 19-year records at Anmyeondo, we estimate regional CO_2 fluxes by comparing CO_2 concentration values (ΔCO_2) when a wind comes from land sectors or ocean sectors. We verify that the CO_2 data at ocean and land sectors act as a background and regional value from analysis of back-trajectories derived from Hybrid Single-Particle Lagrangian Integrated Trajectory model, respectively; 87.8% of ocean sectors' air parcels enter the observation site from ocean side and 79.1% of the land sectors' air parcels enter the observation site from land side, suggesting regional CO_2 fluxes are well separated. We find that climatological annual and growing season (May through October) mean of ΔCO_2 is 0.86 ppm and -1.78 ppm. More detailed results will be shown in the workshop.

Oral Presentations for Session 14: Urban greenhouse gas budget – from novel monitoring networks to source identification

Conveners: Leena Järvi, Andreas Christen

Urban areas are major contributor for the global greenhouse gas emissions to the atmosphere. Understanding in detail the total emissions of urban GHGs, their temporal and spatial distributions, including local hotspots, is a key for reducing their emissions and finding optimal emissions reduction strategies. Urban observations and modelling provide also independent evaluation for emission inventories. Different approaches for the urban greenhouse gas balance and source apportionment exists varying from micrometeorological emission measurements and isotope analyses to urban scale modelling. Novel city-wide measurement platforms including mobile observations are emerging where not only the CO2 is included but also other gases such as CH4 and N2O. At the same time, advances in ground based and satellite remote sensing allow for complementary estimation for urban greenhouse gas emissions.

This session will bring together the different methodologies used to examine and understand the urban greenhouse gas budgets, their emissions and sinks, and dependencies on different environmental factors. We welcome in this session contributions based on conceptual, experimental, observational or modelling approaches.

Anthropogenic and biogenic CO2 fluxes in the Boston urban region

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With the pending withdrawal of the US from the Paris Climate Accord, cities are now leading US actions towards reducing greenhouse gas emissions. Implementing effective mitigation strategies requires the ability to measure and track emissions over time and at various scales. We report CO2 emissions in the Boston, MA urban region from September, 2013 to December, 2014 based on atmospheric observations in an inverse model framework. Continuous atmospheric measurements of CO2 from five sites in and around Boston were combined with a high- resolution bottom up CO2 emission inventory and a Lagrangian particle dispersion model to determine regional emissions. Our model-measurement framework incorporates emissions estimates from submodels for both anthropogenic and biological CO2 fluxes, and development of a CO2 concentration curtain at the boundary of the study region based on a combination of tower measurements and modeled vertical concentration gradients. We demonstrate that an emission inventory with high spatial and temporal resolution and the inclusion of urban biological fluxes are both essential to accurately modeling annual CO2 fluxes using surface measurement -2 -1 networks. We calculated annual average emissions in the Boston region of 0.92 kg C·m ·yr (95% confidence interval: 0.79-1.06), which is 14% higher than the Anthropogenic Carbon Emissions System (ACES) inventory. Based on the capability of the model-measurement approach demonstrated here, we project that our framework will be able to detect changes in CO2 emissions of greater than 18%, providing stakeholders with critical information to assess mitigation efforts in Boston and surrounding areas.

A city to national-scale inverse modeling system to assess the potential of spaceborne CO2 measurements for the monitoring of anthropogenic emissions

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Comprehensive information about anthropogenic CO2 emissions at the scale of power plants, cities, and countries is needed to track the effectiveness of emission reduction policies. To answer that need, the TRAcking Carbon Emissions (TRACE) research project aims to analyze the potential of innovative space based observing systems for the monitoring of greenhouse gas (GHG) emissions across a broad range of spatial scales ranging from local intense point sources to regional and national scales.

TRACE studies the potential of new satellite measurements of atmospheric CO2 to monitor anthropogenic emissions with an end-to-end performance simulation platform which will combine an advanced radiative transfer inverse modeling with an atmospheric inversion system based on a high-resolution atmospheric transport model. This atmospheric inversion system uses a zoomed configuration of the regional transport model CHIMERE which covers most of Western Europe and with a 2km to 1km resolution grid over Northern France, Western Germany and Benelux. The inversion shall estimate at high temporal resolution the emissions of 100-200 cities and power plants in this area and regional budgets in the lower resolution part of the domain.

As a first step, the inversion system is used to study the potential of CO2 spaceborne spectro-imagers to constrain the hourly emissions of the Paris urban area. The sensitivity of the results is analyzed with respect to a large range of spatial resolution, precision and swath of the satellite XCO2 images. The inversion system is also applied to an ensemble of emitting areas located in Belgium with a focus on power plants, cities and

administrative regions. This configuration informs on the potential of satellite data to monitor emissions sources of quantitatively different amplitudes and extensions and whose atmospheric signatures may overlap due to their spatial proximity.

Characterisation of carbon isotopic source signature from CH_4 sources in Germany using mobile measurements

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In this study the carbon isotopic signature ($\delta^{13}CH_4$) of several methane sources in Germany (large-scale area around Heidelberg and North Rhine-Westphalia) are characterised. Therefore, mobile measurements of the emission plume of CH_4 sources are carried out using a cavity ring-down spectrometer (CRDS) G2201-i (Picarro,Inc.,Santa Clara,CA). To achieve precise results the CRDS analyser, which measures methane (CH_4), carbon dioxide (CO_2) and its ^{13}C to ^{12}C ratios, was characterised especially with regard to influences of the gas matrix. The two most important gases which affect the measurements are water (H_2O) and ethane (C_2H_6). To avoid the influence of H_2O the air is dried with a Nafion dryer during mobile measurements. Ethane is abundant in natural gas and thus in methane plumes or samples originating from natural gas. A C_2H_6 correction and calibration is thus essential in order to obtain accurate $\delta^{13}CH_4$ results, which can deviate up to 3‰ whether an ethane correction is applied.

The isotopic signature is determined with the Miller-Tans-Approach and the York fitting method.

During 21 field campaigns we recorded the averaged isotopic $\delta^{13}CH_4$ signature of three dairy farms (-63.9.0±0.9‰), a biogas plant (-62.4±1.2‰), a landfill (-58.7±3.3‰), a wastewater treatment plant (-52.5±1.4‰), an active deep coal mine (-56.0±2.3‰) and two natural gas storage and gas compressor stations (-46.1±4.3‰) .

In addition, between December 2016 and February 2018 gas samples from the Heidelberg natural gas distribution network were measured. Contrary to former measurements between 1991 and 1996 (Levin et al. (1999)) no strong seasonal cycle has been observed. The mean $\delta^{13}CH_4$ value of this study is with -43.2±0.8‰ about 2.9‰ more depleted than in former years.

Investigation of fossil fuel emission detection in the presence of natural carbon cycle variability across the globe.

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Attribution of changes in the atmospheric growth rate (AGR) of CO2 to regional fossil fuel CO2 (FFCO2) emission trajectories using independent atmospheric measurements is critical to support international carbon mitigation such as the Paris Agreement. However, that attribution is contingent on the detection of regional FFCO2 emission trends confounded by natural carbon cycle, which imposes its own spatially dependent trends and variability. Here, we investigate the time-to-detection (TTD) and magnitude of these FFCO2 trends using CMIP5 model ensembles and an idealized CO2-only inversion system. We show that the best-case regional time-to-detection in the total carbon fluxes can range from sub-decadal in regions with large FFCO2 emissions or low vegetation activities, e.g., East Asia and the Middle East, to multi-decadal where

Net Biome Production (NBP) variability, e.g., Southeast US, is dominant. Concomitant trends in the natural carbon cycle lead to divergences between the regional total and fossil fuel (FF) trends. Focusing on the top twenty mega-cities, we show that regional time-to-detection within 5 years is possible in approximately 40% of these mega-cities where either fossil fuel emission use is relatively large or NBP is relatively low. Although these estimates are dependent on the specific FF emission projection and are sensitive to the choice of the ESM, the analysis highlights that the detection and attribution of regional FF emissions to CO2 AGR with atmospheric data will vary considerably between countries. We show how these impose requirements on a prototype global integrated natural and fossil fuel prediction and attribution system that could, in principle, support climate change mitigation.

A low-cost sensor network to monitor the CO2 emissions of the city of Zurich

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The use of low-cost atmospheric sensors is gaining wide interest because of rapid innovations in sensing, data transmission, and data analysis. Dense measurements of CO2 in a city, combined with extensive data analysis and modelling, bears great potential to gain insight into the CO2 sources and sinks to provide policy-relevant information for cities striving to reduce their carbon footprint. Within this context, the project Carbosense has built up a unique CO2 low power sensor network covering Switzerland, including a dense cluster of sensors in the city of Zurich. The network in Zurich is designed around (i) 51 nodes of battery-powered CO2 low-cost diffusive NDIR sensors (SenseAir LP8), (ii) 6 temperature stabilized, mains powered NDIR low-cost instruments (SenseAir HPP) with active sampling and reference gas supply, and (iii) 2 high-precision laser spectrometers (Picarro CRDS) as reference instruments. The LP8 sensors are mounted at radio transmitter antennas and at lamp and electricity poles and transmit their data over Swisscom's new Low Power Network (LoRaWAN). They have been integrated by Decentlab with relative humidity and temperature sensors, and with LoRaWAN communication. All sensors were characterized in climate and pressure chambers and were placed outdoors next to a Picarro reference instrument for several weeks. Extensive characterization of sensor behavior in the field was performed using statistical methods by combining three sources of information: (i) the initial chamber calibrations, (ii) the parallel operation with CRDS before deployment, (iii) using periods with strong winds and correspondingly small spatial gradients to align the signal offsets of all sensors. Here we will present the data collected since August 2017 and a first analysis of the contributions from anthropogenic and biospheric CO2 fluxes supported by high-resolution CO2 simulations over Switzerland (1 km resolution) and Zurich (250 m resolution) with the atmospheric transport model COSMO-GHG.

Posters for Session 14: Urban Greenhouse Gas budget – from novel monitoring networks to source identification.

CH4 from waste: constraints on captured and fugitive emissions from isotopic analysis

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As mitigation of climate change is a key scientific and societal challenge, CH_4 emissions are a major contributor to Europe's global warming impact and emissions are not well quantified yet. There are significant discrepancies between official inventories of emissions and estimates derived from direct atmospheric measurement. Effective emission reduction can only be achieved if sources are properly quantified, and mitigation efforts are verified. Globally, human activities produce over 60% of total CH_4 emissions, with 22% of emissions from the energy sector and 10% from the waste sector.

Methane from waste is dominantly of biogenic origin and can vary with temperature and production process, which results in variation of emissions with time of day and time of year. In addition, the waste sites now commonly produce and combust this biogas, and emissions from each component can be identified by analysing the methane isotopic composition, as different source types are characterized clearly by distinct $\delta^{13}C$ signatures. For landfill sites in particular a percentage of the methane produced is oxidised by soil cap or oxygen in upper-levels of less-compacted waste and this results in a different isotopic signature to non-oxidised methane in the gas extraction system.

This study focuses on identification and quantification of CH_4 emissions from waste sources in the UK. Moreover, off-site plume samples have been collected for isotopic characterization. Picarro and LGR mobile methane measurement systems coupled with the isotope analysis of sampled methane emissions by high precision GC-IRMS have been used to locate and characterise sources of methane emission. Emission plumes from selected landfill, wastewater treatment plants and biogas plants have been assessed, also these sites have been studied in more detail using isotopic characterization of emission plumes from individual site components to distinguish isotopically these from other UK methane sources.

The isotopic signature of carbon dioxide emissions from an urban surface measured using eddy covariance and flux gradient approaches

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Measured urban greenhouse gas emissions can help validating emission inventories and characterising the source mix of emissions. The stable isotope composition of oxygen and carbon in carbon dioxide (CO_2) can provide valuable information about the ratio of various fuel sources in urban environments. To date, linear mixing models have been used to identify the contribution of different fuels (natural gas, gasoline and diesel) and respiratory emissions (from soils, plants, and humans) to the enhanced CO2 in the urban boundary layer. Unfortunately, this is only possible at coarse temporal and spatial resolution. Here we present two approaches to continuously measure isofluxes of the stable isotopologues 12CO2, 13CO2 and CO18O over an urban surface. We employed the eddy covariance (EC) and the flux-gradient technique (FG) on an flux tower located in a residential area of Vancouver, BC, Canada (Fluxnet ID "Ca-VSu"). Half-hourly isoflux ratios were measured between March 15 and July 15, 2016 using a high-frequency, closed-path tuneable diode laser absorption spectroscopy (TDLAS) system. The measured isofluxes from the flux tower are consistent with independent source samples from different exhaust sources and match a detailed, time-disaggregated municipal inventory. The EC-measured isoflux ratios of 13CO2 to 12CO2 and CO18O to 12CO2 change seasonally with heating degree days, as the ratio of natural gas and gasoline in urban emissions shifts from winter to summer, as well as a stronger soil respiration component in summer months. Although overall comparable, the advantage of the EC approach are clearly defined source areas. We argue that selected EC-based measurements of isofluxes over flux towers in European cities would benefit the atmosphere and ecosystem program to provide information about the characteristic (and diurnal and seasonally changing) isotopic composition of urban emission mixes as needed in regional and global inversion models. Unlike signatures determined via the intercept of 'Keeling plots', our direct EC-based isoflux ratios characterises the exact source composition in the tower's source area without the assumption

Nocturnal area fluxes of CH_4, CO_2 and CO for a suburb of Saint-Petersburg

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Urban areas have been known as the significant source of carbon cycle gases in the Earth's atmosphere. Nevertheless the anthropogenic sources vary depending on geographical location, amount of population and developmental level. Therefore continuous monitoring of CH_4, CO_2 and CO concentrations in the ambient air, that is carried out at the observational site located in a suburb of Saint Petersburg (Peterhof), allows us to evaluate the fluxes of these gases, that is one of the prime interest for climate study and forecast.

For the estimation of CH_4, CO_2 and CO fluxes we used accumulation events under nocturnal and calm conditions which were analyzed using a simple box model with consideration of absence of horizontal and vertical fluxes through boundaries of the box (based on the article of M.Zimnoch).

Average values of CH_4, CO_2 and CO fluxes estimated for Peterhof for 2014-2015 are of (44 ± 27), (6100 ± 4000) and (90 ± 100) t/(km2·yr), respectively. However, for the cases of mutual accumulation the average values of CH_4, CO_2 and CO fluxes are of (41 ± 61), (8957 ± 6621) and (40 ± 38) t/(km2·yr), respectively.

Emission ratio analysis for CH_4, CO_2 and CO allowed us to establish the main types of anthropogenic sources for the territory of Peterhof: traffic, natural gas combustion in domestic appliances and industrial plants, during the cold season – using of wood stoves for the heating of mansions located nearby the observational site.

The carbon dioxide emissions of U.S. cities

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Urban areas are rapidly growing and are acknowledged to dominate greenhouse gas (GHG) emissions to the Earth's atmosphere. They are also emerging as centers of climate mitigation leadership and innovation. However, fundamental quantitative analysis of urban GHG emissions beyond individual city case studies remains challenging due to a lack of comprehensive, quantitative, methodologically consistent emissions data, raising barriers to both scientific and policy progress. Here we present the first such analysis across the entire US urban landscape, answering a series of fundamental questions about emissions responsibility, emissions drivers and future trajectories. U.S. cities account for 55% to 92% of total U.S. fossil fuel carbon dioxide (CO2) emissions depending upon the urban boundary definition applied and the accounting viewpoint taken (production versus consumption). In contrast to previous findings, we find that emissions grow slower than urban population growth in Eastern US cities, particularly for larger urban centers. The Western US, by contrast, shows emissions growing proportionately with population. Much of the difference between Eastern versus Western cities is determined by the onroad emissions sector. Collectively, these results suggest that "bigger is better" when considering GHG emissions and U.S. urban population growth. Finally we find large and persistent differences between the results presented here and self-reported urban inventories with the majority of self-reported values lower than quantified in this study.

Spatial modelling of carbon dioxide emissions in central Helsinki – the effect of different planning scenarios

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The highest pressure to reduce atmospheric CO_2 emissions concentrates to cities, and tools to examine the effect of different mitigation strategies to minimize CO_2 emissions to the atmosphere are needed. Urban CO_2 emissions are commonly estimated from emission inventories with bottom-up approach, but the downside of this methodology is the lack of spatial and temporal representativeness of the emissions and information about the biological components participating to the net ecosystem exchange. In order to examine the effectiveness of different urban planning strategies on carbon emissions, ecosystem models including both anthropogenic and biogenic components of CO_2 exchange are needed.

The aim of this study is to examine the spatial variability of CO_2 net exchange and its different components at the scale of 250x250 m^2 in Helsinki using the Surface Urban Energy and Water balance Scheme (SUEWS), where CO_2 surface exchange has recently been added as one of the simulated components in a neighbourhood scale. The new module, describing both the anthropogenic and biogenic components, performs well when evaluated against eddy covariance measured CO_2 flux at two sites in Helsinki. The spatial simulations over an area of 6x9 km2 in 2011-2012 with an hourly resolution shows the different hot spots such as Helsinki city centre and hospital area clearly. Using mobility data, we are able to detect daytime and night-time differences. Within the area, if stationary sources are excluded, road traffic is the major contributor followed by human metabolism. In general, the effect from biogenic components balance each other out and using green areas in mitigating CO_2 emissions within the study area, does not provide to be an efficient tool.

Evaluation of Satellite-Derived Versus Bottom-Up Fossil Fuel CO2 Emissions at the Urban Scale in Four US Urban Domains

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Spatially-resolved fossil fuel CO2 (FFCO2) emissions have found multiple uses in science and policy applications. They are used as a constraint in atmospheric CO2 inverse calculations of surface fluxes, in understanding the socioeconomic drivers of emissions, and in development of mitigation policy at multiple scales. The emergence of cities as loci of CO2 mitigation policy has placed greater need for FF CO2 emissions estimates and verification systems appropriate to the urban domain. Two different scientific approaches have been taken to estimating urban-scale FF CO2 fluxes: satellite-derived (SD) estimation and a bottom-up (BU) engineering approach. Because the BU approach is typically a more labor-intensive approach accomplished in only a few US cities, it is important to quantitatively evaluate the suitability of globally-available SD results for urban-scale application. Here, we present a comparison between results from SD and BU results in four US urban domains: the Los Angeles Basin, Indianapolis, Salt Lake City and Baltimore. At the domain-wide scale we find FFCO2 emission differences ranging from 1.5% (the Los Angeles Basin) up to 20.8% (Salt Lake City). At the scale of individual 1 km x 1 km gridcells, the median difference ranged from 47% to 80%, which could serve as an uncertainty estimate of SD results, particularly when used as a constraint to urban atmospheric CO2 inversions studies. The largest discrepancies were found for large point sources (factories, powerplants) and the onroad sector, suggesting SD FFCO2 data products could be further improved by independently estimating large point-sources and including onroad emissions as a separate emitting category with a relevant spatial surrogate. Finally, we found that the two data products show improved agreement at spatial resolutions greater than approximately 25km2, suggesting a resolution limit to the application of SD emissions to urban-scale analysis.

Methane Emission Mapping and Evaluation across Utrecht City, the Netherlands

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Methane escape from natural gas distribution systems results not only in global warming, but also in economic loss. An estimate from the Boston region implies a financial damage of $90 million as about 15 billion cubic feet of natural gas escape from the distribution system annually (McKain et al., 2015). Although in the Netherlands it has been decided to replace natural gas usage by alternatives by the year 2050, currently about 7 million households use natural gas.

Between February and April of 2018, we have carried out extensive campaigns to measure methane concentrations in Utrecht, Netherlands, at the street level using a Picarro inc. fast methane analyzer mounted on a small van. The campaign logistics were based on stable weather conditions, avoiding traffic rush hours, and passing each street at least two times.

The results highlight small-scale methane elevations that are related possibly to losses from the gas distribution system and a domestic waste-water treatment plant. Hot spots were categorized using the empirical equation from Von Fischer et al. (2017) to translate the concentration elevations to emissions.

Hotspots were revisited to confirm their continuous persistence and many of the hotspots were not seen in revisits. Consistently high methane elevation was recorded in all campaigns from the waste water treatment plant.

Utrecht is the first city in the Netherlands where methane concentration has been mapped across the entire city. The results show a significantly cleaner situation in Utrecht compared to Boston.

Urban flux monitoring in a Mediterranean city

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Human activities release energy in the form of heat, as well as greenhouse gases (GHG) (mainly carbon dioxide). All these processes have an impact on the urban climate by modifying the energy flux partitioning and the carbon budget. Monitoring urban energy and carbon fluxes could help in understanding the role of anthropogenic activities in the local energy and carbon balance.

Flux measurements were carried out, through Eddy Covariance technique, in the city of Sassari, located in the north of Sardinia Island (Italy), to study the exchange of energy, water, and carbon over the city, evaluate their impact on human livability, and understand the main factors or activities affecting them.

The area surrounding the measurement tower has less than 20% of vegetation cover and measured fluxes were sorted by wind direction to better investigate the role of this reduced vegetation amount in decreasing anthropogenic fluxes, which could help the municipality to identify possible actions for mitigating human impact. Results showed the traffic is one of the main sources of carbon emissions, with two distinguishable peaks clearly related to the rush hours during the working days (morning and evening peaks), as well as an additional peak during lunch time, typical in a Mediterranean contest.

GHG fluxes measurements in Lodz, Poland – selected results from the period 2006-2018

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The aim of the study is to present selected results of measurements of turbulent exchange of carbon dioxide (FCO2) and methane (FCH4) in Lodz, Poland. Continuous measurements of these fluxes are carried out in Lodz since 2006 (carbon dioxide) and 2013 (methane) on two sites – in the center of Lodz (2006-2015) and in the postindustrial district (2016 – 2018). The fluxes were determined using eddy covariance method - the most accurate and currently the most widely used for continuous, long-term measurements of turbulent exchange of mass, energy and momentum. During the measurements, a standard instrumentation set consisting of an ultrasonic anemometer (RMYoung, USA) and water vapor, carbon dioxide and methane analyzers was used (LI7500 and LI7700, Licor, USA). The results of measurements show, both, similarities and differences in seasonal and, especially, diurnal variability of FCO2 and FCH4 registered on sites. All measured turbulent fluxes are characterized by a more (city center) or less (postindustrial district) clear annual rhythm. FCO2 and FCH4 temporal variability in Lodz are strongly related to anthropogenic emission of carbon dioxide and methane during wintertime. In warm half of a year anthropogenic emissions are less intense and FCO2 flux is, in certain degree, additionally compensated by carbon dioxide uptake by urban plants. Diurnal patterns of FCO2 are observed all year long, while in the case of FCH4 such phenomena is observed mainly during wintertime. Typical for urban areas weekly variability of FCO2 is clearly visible, while in the case of FCH4 differences between working days and weekends are much less significant.

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Investigating the urban climate using Radon-222 – Lodz, Central Poland case study

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A recently-developed radon-based nocturnal stability classification technique (Chambers et al. 2015; Atmos. Chem. Phys., 15, 1175-1190) was used to characterise the local (25-50 km scale) atmospheric mixing state, and then investigate the climatic influence of a compact (10-15 km diameter) urban centre as a function of the local stability. Four years (2008-2011) of paired hourly near-surface meteorological and atmospheric radon measurements from adjacent urban and rural sites were analyzed. The urban station was located in the centre of Lodz (3rd most populated city in Poland, ca 725,000 inhabitants, area 293 km2). The rural station was located 25 km to the north, in the district of Ciosny, and is representative of typical agricultural land with low vegetation and sparse dwellings. The radon-based stability classification technique was employed to characterise the Urban Heat Island Intensity, radiation balance, sensible heat flux, latent heat flux, surface energy budget, near-surface temperature gradient, wind speed, and humidity over the full diurnal cycle for five distinct atmospheric mixing states. This radon-based technique is demonstrated to be an effective tool for assessing the efficacy of mitigation measures for urban climate effects in a consistent way over timescales of years to decades. The consistency of approach, ease of application, and unprecedented clarity of findings, provide a strong argument for atmospheric radon observations to be included as part of the 'standard measurement suite' for urban climate monitoring networks for non-coastal cities.

MExico city's Regional Carbon Impacts (MERCI-CO2)

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Mexico City (MC) is the home of 21.2M people, with intense emissions of pollutants and greenhouse gases, which accumulate in the overlying air-shed due to the location of the city in a basin surrounded by

mountains. Local authorities have engaged in emission reduction activities. The purpose of the French-Mexican project MERCI-CO2 is to set up atmospheric CO2 measurements and analysis tools that will permit the verification of CO2 emission reductions. As part of this project we shall measure atmospheric CO2 concentrations gradients within and around MC, attribute them to emissions from the city, and combine them with an atmospheric transport model and emission inventories to reduce the uncertainty on CO2 emissions in support of reduction policies taken by regional authorities.

Given the huge extent of MC, sampling the atmosphere to best capture its CO2 emissions is a scientific challenge, which requires several monitoring stations. The proposed solution is to deploy an array of 10 novel low-cost medium precision (LCMP) CO2 sensors with two high-precision instruments. The locations of LCMP will be selected after analysis of existing air quality observations and gridded CO2 emissions fields. Combining CO2, CO and NOx observations will help us to identify the contribution of different emission sectors (traffic, residential, industry). CO2 concentrations measured in the boundary layer will be complemented by total air column observations. These measurements will characterize large-scale CO2 gradients between upwind and downwind of MC, providing an independent check of total city emissions, and a bridge to satellite observations of the CO2 column. Both measurements will be compared to simulations from a high-resolution model prescribed with city-scale CO2 emission maps. The inversion of selected CO2 gradients in an analytical Bayesian inversion framework will allow estimating MC emissions, which will be compared to the existing official inventory (based on energy use and fuel statistics).

The GROOF project : Greenhouses to Reduce CO2 on Roofs in urban area

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The GROOF project is an innovative cross-sectorial approach to reduce CO2 emissions in the construction and agricultural sectors by combining energy sharing and local food production. The idea is to use roof greenhouses as a tool for (1) recovering heat generated by the building that supports the greenhouse, both actively (through the ventilation system) and passively (30% heat lost through the roofs on average) in vegetables and herbs production, (2) collecting CO2 produced by human activity and building activities to "feed" the plants, (3) reduce transport-generated CO2 emissions by producing fresh vegetables locally. The greenhouse itself is an extra activity located outside of the building but sharing energy with it in order to make both of the structures more efficient. Concretely, GROOF will facilitate the emergence of this type of greenhouse on the market by demonstrating and disseminating among the actors of construction and agriculture good practices favorable to the development of profitable and functional business and social models. GROOF will focus on the four main aspects associated with roof greenhouse project: (a) Construction: technical, urban planning rules, regulations, insurance, etc. (b) Energy performance of rooftop greenhouse (c) Socio-economical: business and social models (d) Plant production. For each of these aspects, GROOF will: (i) Identify barriers to market access (ii) Create a state of the art based on literature and experience of existing roof greenhouse. This will provide tools to overcome the barrier and facilitate new projects. (iii) Experiment, validate and demonstrate the effectiveness of roof greenhouses. Four pilot roof greenhouses will be created within the project partners. These greenhouses, along with existing rooftop greenhouses will be used to formalize the four aspects described above using scientific methodologies. (iii) Support new rooftop greenhouse projects. The results of each GROOF will be shared with the target communities.

Eddy Covariance measurements and source partitioning of CO_2 emissions in urban environment: application for Heraklion, Greece

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Cities are now becoming the focus for CO_2 emission reduction efforts worldwide and there is a growing need for establishing emission inventories, developing methodologies for improved CO_2 monitoring and understanding of the multiple source, sink and storage processes inside the complex urban environment. This study combines Eddy Covariance (EC) measurements of CO_2 flux (FC) over the city centre of Heraklion with analytical morphological and land cover data to achieve a thorough investigation of the spatiotemporal variability and the controlling factors of FC in the urban setting. The detailed characterization of the urban land cover and 3D structure was performed using very high resolution Earth Observation data. The urban morphological data was used to parametrize a turbulent flux source area model and the land cover data to analyse the contribution of the source area components to the measured FC. Heraklion FC does not present any specific seasonal trend according to the meteorological or vegetation changes throughout the year. Heraklion centre behaves as a net emitter diurnally and throughout the year. The diurnal variability presents a standard pattern in weekdays with a major peak in midday and a secondary in afternoon, clearly following the traffic rush-hour peaks. Building space heating emissions during winter remain low, while an important factor of the total CO_2 emissions is human metabolism. Vegetation has minor effects to the annual FC budget due to the scarce green areas in Heraklion centre. The main CO_2 hotspots are the major roads and the intersections, where the heavy traffic is located. The total annual emissions of Heraklion centre reach over 19 kg CO_2 m^{-2} y^{-1}, which is significantly high compared to other reported city emissions.

Urban Ecosystem Services: Climate Change Mitigation and Resilience of Cities.

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Cities for citizens provide a wide range of function and services such as education, jobs and culture and they are also known as the engine of regional development. But the fast expanding of the cities with permanently increasing concentration of population brings the great pressure on the balance of the environment, with climate extremes seriously effecting human health (McMichael, et al, 2003)(Patz, et al, 2005). How cities are planned and structured exacerbates the negative effect of climate change. Ecosystem services, such as climate regulation are functions of nature that provides wide range of benefits to humans and healthy environment. Green infrastructure offers these services in urban environment lowering carbon stock in the atmosphere and increasing resilience of the cities (EFB, 2015). Thus largely contributing to the article 4.1. of the Paris Agreement. Mainstreaming ecosystem services into spatial planning in cities can bring a numerous benefits for quality of life in cities. We identify how cities can benefits from green infrastructure in terms of climate change mitigation and human well being. The paper concern effective green infrastructure management as urban heat islands. In particular we determine i) what are major climate change risks perceived by key actors? ii) how to reform city management by considering the role and potential of regulatory ecosystem services in a long – term? iii) how to stimulate behavioural change of ecosystem

services providers and users to climate change adaptation in cities? Paper evaluates the perception of risk of climate change with use semi structure interviews with key actors in these cities (Bratislava, Trnava, Ružomberok from Slovak Republic compared to similar cities in the Czech Republic). Measurement temperature and humidity in two courtyard (with greenery and without greenery) as evidence of the benefit green infrastructure can provide to reduce effect of heat islands.

Assessing atmospheric CO2 variability in the Aix-Marseille metropolis area (France) and its coastal Mediterranean Sea at different time scales within the AMC project.

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Urbanized areas are the major emitter of anthropogenic CO2, which is today the main additional atmospheric greenhouse gas. However, their current emissions estimates, but also how these estimates are balance by carbon sinks, have significant uncertainties at the regional scale. These questions can be adressed by developing regional atmospheric approaches, which combine mescoscale observations and modeling of atmospheric CO2. Such approaches have already been successfully developed for example in Paris (through the CO2-Megaparis project, e.g. Xueref-Remy et al, 2018 ; Lac et al, 2013), in Indianopolis (through the INFLUX project ; e.g. Turnbull et al, 2015) and in Los Angeles (through the MEGACITIES project ; e.g. Verlhust et al, 2017). According to IPCC (2013), the « SUD Region » (located in the south-east part of France), and its coastal Mediterranean Sea are particularly exposed to the risks of climate change. The SUD region comprises the Aix-Marseille metropolis, which is the second urban area of France in terms of population. In the framework of the Aix-Marseille Metropolis Carbon (AMC) pilot study, we are developing a top-down approach to verify the available regional emission inventories and to estimate the carbon sinks of the SUD region and of its coastal sea. In this aim, since 2016 we developed a mesoscale in-situ observation network to identify the factors that influence the regional atmospheric CO2 concentration and that will be presented in this study. Our network extends on a rural-urban-coastal-marine gradient that includes two ICOS stations : OHP (Observatoire de Haute Provence) and ERSA (Cap Corsica), that we use to define the background CO2 concentration (i.e. without the influence of regional emissions). The role of sources vs sinks is assessed through the use of tracers measurements (CO, NOx), on the diurnal to the seasonal scales. A particular attention is paid to the role of atmospheric dynamics and meteorological conditions on the variability of atmospheric CO2, as the region is characterized by specific synoptic conditions but also by local weather processes arising from its geographical features (coastal Sea, complex topography, urban heat island). Especially in Marseille, we will show how land-sea breezes and local wind patterns impact the CO2 concentration observed in the city. We will also show the influence of remote emissions on the regional CO2 concentration at OHP and ERSA stations. Eventually, we will present our carbon isotopes measurement program (to infer the relative role of fossil fuel emissions vs those of modern sources and carbon sinks) and our mesoscale modeling framework (including Large Eddy Scale simulations), both under development.

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Mobile measurement of methane in Ile de France region

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The main goal of MEMO² project is the identification and evaluation of the methane emission at the European scale. The PhD thesis "Characterizing CH_4 emission in urban environments" is part of the milestones to achieve this goal. Measurements focused on Paris city and other urban-related anthropogenic sources like gas compressor stations or landfills allow to better understand urban fugitive emissions. To achieve this goal, mobile measurements are made using the trace release method. This method associated with plume modeling let not only measure concentration but also estimate emission from source. Moreover, during campaigns isotopic composition of methane was measured, to extend knowledge about methane isotopic composition of European anthropogenic source. Here we present data from campaigns realized during first year of PhD study as well as results from specific tests performed on the CRDS analyzers used during campaigns. Part of these test was focused on cross sensitivity with other species. Significant ethane influence for $\delta^{13}CH_4$ was evaluated and required correction was calculated. This correction is necessary especially in measurement sites with presence of ethane emissions like sites emitting natural gas.

Oral Presentations for Session 15: In-situ and remote sensing observations

Conveners: Corinna Rebmann, Marko Scholze

In the local level, fluxes are understood with rather small uncertainty with flux towers. Uncertainty is also relatively small in the global scale with flask and continuous tall tower sampling networks. Our understanding of fluxes reduces greatly when we move to the scale between these two – the scale of individual countries. At the same time, this scale is of high interest due to many scientific and political challenges. Reducing the uncertainty is effectively done by advances between in situ, remote sensing and modelling communities. This session addresses the complementing roles of in situ and remote sensing observations and the benefits of combining these methodologies.

A strategy for estimating yield and the components of the carbon and water budgets for croplands at plot scale over large areas

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Developing diagnostic tools for assessing C and water budgets, monitor crop production at the plot scale over large areas (region, country) is essential for guiding the transition of conventional agriculture toward more sustainable practices. We propose here a regional modeling approach that combines high spatial and temporal resolutions (HSTR) remote sensing data, a simple crop model and in-situ flux data for model's validation. This approach could be applied at European scale in a near future thanks to the new Sentinel satellite constellation.

The model, called SAFYE-CO2 is a daily time step model based on Monteith's light-use efficiency theory and coupled with a water budget module (FAO-56 method). SAFYE-CO2 estimates the components of the carbon and water budgets and also time courses of dry aboveground biomass and yield. Crop and soil model parameters were determined using both in-situ measurements and values found in the literature. The phonological parameters and the light use efficiency were calibrated by comparing the Green Area Index (GAI) simulated by the model with the GAI dynamics estimated from satellite observations. For this work, we used a unique set of Sentinel 2 like data (Formosat-2 and SPOT) images acquired from 2006 to 2011 in southwest France. The results indicate that the model is able to correctly reproduce the biomass and yield production (relative error about 25%) for years with contrasted climatic conditions. The estimated net carbon flux components were overall in agreement with the measurements, presenting very good correlations (R^2 about 0.9 for GPP, 0.77 for Reco and 0.84 for NEE). Carbon and water budgets, as well as some water use efficiency (WUE) indices were computed, allowing to evaluate the crop ecosystems in terms of environmental and agronomical aspects. The performances of this method was improved by considering weeds or re-growths events after harvest.

Measurement-based upscaling of pan-arctic net ecosystem exchange

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The arctic tundra is heterogeneous. Whereas eddy covariance measurements of net ecosystem exchange (NEE) of CO_2 are highly accurate for the target ecosystem, our knowledge of the spatial variability in carbon cycling among tundra ecosystem types is still poor. Previous studies have demonstrated that the tundra shows strong functional convergence, such that the quantity of above-ground vegetation is a key determinant of spatial variation in NEE.

In this study, we developed and tested a simple pan-arctic NEE model (PanEEx) using the Misterlich light response curve (LRC) function. Model calibration was carried out based on eddy covariance CO_2 flux data from 12 arctic tundra sites. The model input parameters (Fcsat, Rd and α) were estimated as a function of mean July normalized difference vegetation index (NDVI) available at 250 m resolution through the MODIS Terra product MOD13Q1. The LRC was driven by 3-hourly photosynthetic photon flux density (PPFD) data derived from the global land surface product GLASS PAR. Data processing was performed in Google Earth Engine.

The PanEEx model is capable of producing spatially integrated time series of summertime NEE, which is highly useful as a benchmark for global vegetation models. In this presentation, we will present preliminary results including model validation using independent data sets. Model parameterization can be improved once more data become available from the arctic domain. Furthermore, a similar approach may also be applicable to other biomes.

Exotic observational sites: nuisance or critical test beds

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For many of the environmental issues we are facing, it is no longer possible for a single investigator, or even a team of investigators, to address large-scale ecological questions. Coordinated distributed biogeochemical research based on international collaborations are needed to address problems at regional and global scales in order to understand ecological patterns and processes, and to develop solutions for environmental management based on sound scientific data. Several key components of global change research are often recognized: First, a long-term research approach is needed. Second, large-scale context of the study and its environmental representation. Third, a combination of observational research, experimental manipulations, and modeling.

In particular, ‘experiments’ permit the formulation of theory. Models are usually built upon knowledge of ecosystem processes, and are often parameterized by observations and experimental manipulation data. Observations can be used to test the adequacy for theory to represent processes, and provide validation through the assimilation of observations into the models.

Testing theory and models in the same framework employed in their development does not always provide the rigorous testing ultimately needed. Instead, models, numerical, analytical and conceptual ones, should be tested in the less 'conventional' settings that truly test their robustness. The more exotic observational sites that do not always fit the large-scale patterns provide such important tests. We will review a series of examples from the Yatir site operating at the "dry timberline" for past 18 years, that demonstrate 'non-conventional' ecosystem response to environmental conditions, including response to extreme events, changes in phenology, energy flux partitioning, and remote sensing signals, all of which provide demanding challenges to some of our traditional assumption.

Integration of flux tower data and remotely sensed data into the SCOPE simulator: A Bayesian approach

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Quantification of gross primary production (GPP) together with the continuous monitoring of its temporal variations are indispensable to obtain reliable data for indicating the capacity of forests to sequester carbon. GPP can be quantified using two sources: (a) process-based simulator (PBS); and (b) flux tower measurements of the net ecosystem exchange (NEE) of CO2. Additionally, remotely sensed optical data, which can be linked to the vegetation properties, carry valuable information to express canopy photosynthesis (i.e., GPP). A PBS has an advantage over flux tower and remotely sensed optical data because it can be run at time scales beyond the limit of direct measurements. Simulation of GPP by PBS at a high accuracy, however, depends upon how well the parameterization is achieved. A process-based simulator SCOPE (Soil-Canopy-Observation of Photosynthesis and Energy balance) links top of canopy observations of radiance with land surface processes (that include GPP simulation). Some parameters of SCOPE are difficult to obtain from field observations. Reliable estimates of parameters can, however, be obtained using calibration against observations of output. In this study, we present a Bayesian framework to calibrate SCOPE simulator against the estimates of GPP (separated from NEE), and the top of canopy reflectance retrieved from the remote sensing images. This framework has been tested for spruce dominated forest site at Bílý Kříž, Czech Republic. We focus on the retrieval of parameters, on which GPP are expected to be most sensitive, such as leaf area index, leaf chlorophyll content, leaf water content, leaf dry matter content, senescent material content, maximum carboxylation capacity, and stomatal conductance. A Bayesian framework also allowed to estimate the uncertainties of both the SCOPE parameters and the simulated GPP, which is important in the sense that it helps to determine how much confidence can be placed in the results of forest carbon-related studies.

Quantifying evapotranspiration from satellite retrievals of land surface temperature over a mosaic landscape in the Czech Republic

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Evapotranspiration (ET) is the key part of the land water balance. Although advanced techniques, like eddy covariance (EC), are available, routine measurements providing information about ET at the field scale and at a density enabling to capture the ET spatial variability is still lacking. In contrast to in-situ observations, remote sensing (RS) estimates of ET through land surface temperature (LST) has the capability to provide complete land spatial coverage. Although the high spatial resolution of RS techniques applicable for field scale analyses is compromised by low time resolution, the high resolution in both time and space can be attained by combining satellite imaging with different spatiotemporal characteristics. In this study, we tested a global product of Atmosphere-Land Exchange Inverse model relying on LST retrievals from a Moderate Resolution Imaging Spectroradiometer sensor on the Aqua platform. Since the resolution of this product is ~5 km, a disaggregation approach using biweekly Landsat 8 with subsequent image sharpening and Spatial and Temporal Adaptive Reflectance Fusion Model was used to obtain daily ET with 30 m resolution. These RS estimates were compared with EC measurements at a 26-ha spring barley field in Polkovice (49.4 N, 17.3 E, 200 m a.s.l., the Czech Republic) in 2016. The RS ET estimates exceeded EC measurements by 14 %. Forcing EC measurements to close the energy balance by assigning the entire energy residuum to latent heat flux, RS ET became 4 % lower than EC ET. By assigning the energy residuum to both latent and sensible heat fluxes according to Bowen ratio, RS ET became only 2 % lower than EC ET. Our study shows that LST based remote sensing techniques provide a physically based and effective means to study ET in a mosaic landscape.

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Posters for Session 15: In-situ and remote sensing observations

Spatio-temporal mapping of daily photosynthesis in drought conditions using remote sensing observations and in-situ measurements

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Reliable spatio-temporal information about the photosynthesis and its dependence on environmental factors, is crucial for vegetation productivity monitoring, water resources management, and detection of climate change effects.. In this study, we investigated the relationship between time series of Landsat (TM5 and ETM7) optical data, soil moisture measurements and canopy daily photosynthesis of annual C3 grasses at a Fluxnet site (US-Var) during a prolonged drought episode from January to August 2004. By using the 'Soil-Canopy Observation of Photosynthesis and Energy fluxes' (SCOPE) model, time series maps of photosynthesis were simulated via Landsat retrieved vegetation properties maps [notably Leaf Area Index (LAI), leaf chlorophyll content (Cab), leaf water content (Cw), leaf dry matter content (Cdm), the leaf inclination distribution function (LIDF) and the senescent material content (Cs)], locally measured weather data and in-situ soil moisture data. The generated maps of photosynthesis simulated by the SCOPE model were validated at a Fluxnet site (US-Var). The comparison between daily photosynthesis simulations and measurements shows that considerable drought effects on photosynthesis are 'visible' in the Landsat optical bands. However, the most accurate photosynthesis maps are obtained when soil moisture information is added as an extra source of input data to the SCOPE simulations. The results from this study indicate that the combined use of optical remote sensing observations and in-situ measured soil moisture data has a great potential to capture the drought effects on the grass canopy photosynthesis.

Combining airborne and ground based remote sensing (lidar, spectrometer) as well as in-situ techniques to determine CH_4 emissions of a European CH_4 emission hot spot area – initial results from COMET

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In order to improve our knowledge on emissions of the second most important anthropogenic greenhouse gas Methane (CH4), a coordinated measurement campaign in the Upper Silesian Coal Basin (USCB) in Poland, one of Europe's anthropogenic CH4 hot spots, will be executed. The 4 weeks campaign in May/June 2018 will be carried out by a team of scientists deploying in-situ and remote sensing instruments on three aircrafts as well as on ground. Two Cessna aircraft – one equipped with in-situ sensors for CH4 and related gases, another equipped with the CH4 remote sensing instrument MAMAP - will concentrate on characterizing the CH4 distribution in the USCB with great horizontal and vertical detail. The German research aircraft HALO - equipped with the CH4 and CO2 detecting lidar CHARM-F, as well as with in-situ sensors – will provide the larger scale picture about atmospheric CH4 distributions. These aircraft based measurements are complemented by ground based measurements: several ground-based FTIR instruments as well as wind lidars will be deployed. In addition, in-situ measurements from mobile vans and small drones will provide near-surface information of CH4. GOSAT and Sentinel-5P CH4 products will be be compared with the ground-based and airborne data. In order to assess regional and local scale fluxes using the data set collected, a hierarchy of modelling approaches (mass balance/Gaussian plume modelling, regional inverse modelling, chemistry-climate modelling with regional refinement) will be used. The paper will present initial findings from the CoMet campaign in the Upper Silesian Coal Basin with a focus on CH4 and steps towards the exploitation of the observations.

The AmeriFlux Management Project: overview, outreach, tech updates and online activities.

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The AmeriFlux network is a community of sites and scientists measuring ecosystem carbon, water, and energy fluxes across the Americas using eddy covariance techniques. AmeriFlux datasets, and the understanding derived from them, provide crucial linkages between terrestrial ecosystem processes and climate-relevant responses at landscape, regional, and continental scales.

The AmeriFlux Management Project (AMP) was established by the U.S. Department of Energy in 2012 to support AmeriFlux and the use of its data by a broad community. We work to advance the value of the network for basic research and Earth System Model improvement, innovative measurements, and data synthesis. The data team provides a wide array of services to the flux tower teams and data users including: an archive, QA/QC processing, DOIs, and standardization of flux data.

The tech team strengthens the AmeriFlux Network by standardizing operational practices, developing calibration and maintenance routines, and setting clear data quality goals. The outreach team bring the AmeriFlux community together organizing the annual data-tech workshop and PI meeting. The AmeriFlux network is strong and growing. Since 2012, the number of AmeriFlux sites has nearly doubled, to more than 350, with more sites outside the U.S. and in underrepresented ecosystems. AMP is supporting operations for 14 clusters of long-term flux sites, maintaining the continuity and accessibility of these time series. The AmeriFlux Science Steering Committee is operating under a new, more independent charter. In collaboration with ICOS (Europe) and FLUXNET (global) networks, in the past year we completed the release of the FLUXNET2015 dataset for synthesis research.

This poster will provide highlights of recent, tech, and outreach activities and accomplishments, and solicit input on how we can continue to improve our service to data contributors and data users.

Standardised, precise and unbiased measurements of above-ground biomass with terrestrial LiDAR

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Bert Gielen, Biology, UAntwerpen, Antwerpen, Belgium, Kim Calders, Environment, UGent, Gent, Belgium, Ivan Janssens, UAntwerpen, Antwerpen, Belgium, Verbeeck Hans, Environment, UGent, Gent, Belgium

Strong efforts are made to better estimate the terrestrial carbon pool with the upcoming launch of several biomass mapping satellites (e.g. ESA BIOMASS and NASA GEDI) and the establishment of the long-term pan-European Integrated Carbon Observation System (ICOS). These initiatives rely on essential ground-reference data of biomass for calibration/validation. However, the use of tree allometric equations to estimate above-ground biomass is contested, because these estimates are often unrepresentative and insufficiently accurate. As an alternative, we use 3D terrestrial LiDAR as a method for unbiased, more precise and traceable biomass measurements. 3D LiDAR data are generally converted into virtual forests using quantitative structure modelling (QSM), which allows inferring biomass and other forest structural parameters. We present the results of a destructive validation experiment of this novel technique on 60 trees in four Belgian sites. We compared the TLS derived biomass with traditional diameter(/height)--biomass relations, and weighed the trees in the field for validation. Subsequently, we will detail the implementation of terrestrial LiDAR for the standardised acquisition of 3D scans across all 35 ICOS forest sites in 9 European countries. An ICOS-specific protocol is developed for this.

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Standardised, precise and unbiased measurements of above-ground biomass with terrestrial LiDAR

Demol Miro, Biology/Environment, UAntwerpen & UGent, Gent, Belgium

Bert Gielen, Biology, UAntwerpen, Antwerpen, Belgium, Kim Calders, Environment, UGent, Gent, Belgium, Ivan Janssens, UAntwerpen, Antwerpen, Belgium, Verbeeck Hans, Environment, UGent, Gent, Belgium

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Two decades of ecosystem CO2 gas exchange above a sub-alpine coniferous forest in Switzerland

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Thomas Baur, ETH Zurich, Zurich, Switzerland, Werner Eugster, ETH Zurich, Zurich, Switzerland, Sophia Etzold, WSL, Birmensdorf, Switzerland, Rudolf Haesler, WSL, Birmensdorf, Switzerland, Florian Käslin, ETH Zurich, Zurich, Switzerland, Philip Meier, ETH Zurich, Zurich, Switzerland, Lutz Merbold, Mazingira Centre (ILRI), Nairobi, Kenya, Peter Pluess, ETH Zurich, Zurich, Switzerland, Sebastian Zielis, ETH Zurich, Zurich, Switzerland, Nina Buchmann, ETH Zurich, Zurich, Switzerland, Mana Gharun, ETH Zurich, Zurich, Switzerland, Matthias Häni, WSL, Birmensdorf, Switzerland, Susanne Burri, ETH Zurich, Zurich, Switzerland

The ICOS Class 1 Ecosystem Station candidate site in Davos, located in a sub-alpine coniferous forest in Switzerland, is one of the longest running eddy covariance (EC) flux stations in the world. Carbon exchange above the canopy, i.e. fluxes of CO2, were first recorded in 1995, continuous measurements are available since 1997. The availability of these long-term measurements allows detailed analyses of intra- as well as inter-annual variability of forest carbon dynamics and thus facilitates the identification of potential trends in ecosystem functioning over a time period of two decades. An additional EC system for CO2 fluxes, compliant with ICOS guidelines, was installed in 2014.

Here we present CO2 flux results from the last 20 years and give insights into the complex functioning of the forest ecosystem in response to biotic and abiotic drivers. Flux calculations for all years were standardized, with each year following the same processing steps and corrections. To ensure only data of highest quality go into subsequent analyses, all fluxes were subjected to rigorous quality tests, consistent among all years. In addition, we compare new fluxes from the ICOS eddy covariance system with fluxes from the previously installed EC system between 2014 and 2016. This comparison aims to investigate the impact of switching to the ICOS EC setup on observed ecosystem fluxes in order to identify potential offsets between the two EC systems.

FTS and AirCore measurements of greenhouse gases at Sodankylä, Finland

Kivi Rigel, Space and Earth Observation Centre, Finnish Meteorological Institute, Sodankylä, Finland

Pauli Heikkinen, Finnish Meteorological Institute, Sodankylä, Finland, Juha Hatakka, Finnish Meteorological Institute, Helsinki, Finland, Tuomas Laurila, Finnish Meteorological Institute, Helsinki, Finland, Huilin Chen, University of Groningen, Groningen, Netherlands

Measurements of column CO_2 and CH4 are made at the Total Carbon Column Observing Network (TCCON) sites worldwide, using solar Fourier Transform Spectrometers (FTS), operating in the near infrared spectral region. Here we present measurements at the Sodankylä TCCON site (67.4° N, 26.6° E). We find that since year 2009 column CO_2 has increased by 2.3 ± 0.2 ppm/year, while the column CH_4 values have increased by 7 ± 0.5 ppb/year. Comparisons with the collocated Greenhouse gases Observing SATellite (GOSAT) observations show good agreement: the relative difference in XCO_2 measurements has been 0.04 ± 0.02% and the relative difference in XCH_4 has been -0.07 ± 0.02 %. At the Sodankylä TCCON site we have performed AirCore in situ measurements during all seasons. The AirCore measurements are used here to study accuracy of the remote sensing retrievals of CO_2 and CH_4. AirCore profiles cover troposphere and lower stratosphere. In addition tower in situ measurements by a Cavity Ring Down Spectrometer in the vicinity of the TCCON site are used to provide accurate CO_2 and CH_4 data near the surface, at 2, 23 and 50 m altitude.

Estimating pan Arctic net ecosystem exchange based on remotely sensed data: the PANEEx project 2018

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Increased temperatures in high latitudes may alter carbon dynamics throughout the Arctic. Modelled CO2 simulations show that the Arctic is a net carbon sink under current climate conditions. However, the large extent and fine landscape heterogeneity raise an uncertainty about the carbon sink/source status of the region. There is a great potential in reducing the knowledge gap surrounding the Arctic carbon dynamics by using remote sensing techniques and environmental modelling. Satellite-based MODIS NDVI (normalized difference vegetation index) and PPFD (Photosynthetic photon flux density) indices are used in the Pan-Arctic Net Ecosystem Exchange (PANEEx) model to calculate NEE (net ecosystem exchange) at 12 Arctic study sites. The model input utilizes light response curve parameters (fcsat, Rd and α) that represent specific characteristics of the NEE-PPFD relationship, including the saturation flux, dark respiration and initial light use efficiency respectively. Here, the main objective is to (i) estimate and upscale Arctic NEE at 250 m resolution and (ii) produce an Arctic NEE map for peak growing season in from 2008 to 2010. Data from eddy covariance towers, ICOS and INTERACT stations are used to compare modelled and in situ NEE data. Google Earth Engine (GEE, Google Inc.), a powerful geospatial platform, was used for the acquisition and integration of the large spatial datasets as well as the quantitative analysis. Preliminary results show that this method effectively describes Arctic NEE at high Arctic sites without prior knowledge of the vegetation type. Consideration needs to be given to high NDVI areas, for which the PANEEx model is not parametrized. Model simulations demonstrate the need of employing satellite data on much finer scale, i.e. 10-30 m in order to capture the Arctic heterogeneous landscape. Despite this, the method shows strong potential for environmental modelling and monitoring of large, remote areas across the Arctic.

Vertical profiles of GHG concentrations at Tall Towers

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Vertical gradients of greenhouse gases from tall tower observations contain useful information with respect to vertical fluxes and quality control (QC). Under well mixed conditions no significant vertical gradients are expected and non-negligible gradients could point to substantial artefacts in the sampling system for one or several heights.

Here, we use one year of hourly data from several ICOS atmospheric stations to derive a quality control procedure utilizing the vertical gradient observations. Well-mixed conditions are selected by filtering for a defined temperature gradient from the lowest measurement level (temperature T_1) to the highest Tn with $T_1 > T_2 > ... >$ Tn . Preliminary results show that the temperature gradient is sufficient for defining well mixed conditions with a better performance than e.g. a friction velocity (u*) threshold. For those selected well-mixed conditions, maximum absolute differences between the detected greenhouse gas concentration of a specific height and the average over all sampling heights are calculated. QC-thresholds for CO_2, CH_4, CO and N_2O are recommended demonstrating that vertical profiles under well mixed conditions can generally be used for quality control of tall tower measurements.

Methane fluxes and isotopic signatures from plant community to ecosystem scale

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Patrik Vestin, Department of Physical Geography and Ecosystem Sci, Lund University, Lund, Sweden, Per Weslien, Departement of Earth Sciences, University of Gothenburg, Gothenburg, Sweden, Natascha Kljun, Centre for Environmental and Climate Research, Lund University, Lund, Sweden, Lena Ström, Department of Physical

Geography and Ecosystem Sci, Lund University, Lund, Sweden, Leif Klemedtsson, Departement of Earth Sciences, University of Gothenburg, Gothenburg, Sweden

Methane fluxes from peatlands show considerable temporal and spatial variation across different scales. These variations have been observed by e.g. manual and automatic chamber measurements, and more recently with eddy covariance measurements. The spatial variations in the microtopographic scale can be due to e.g. differences in methane production/oxidation due to local water table, or differences in carbon sources and subsequent methanogenic processes. The temporal variations in seasonal scale can be due to carbon input, or temperature control of methanogenesis.

Most molecular and biological processes discriminate the heavier isotopes thus altering the isotopic signature of the emitted methane. Thus, stable isotopic signatures of emitted methane can constrain the on the theories on the variation of methane emission. With the recent advances of the laser spectrometry, measurements of e.g. stable carbon isotope ^{13}C in methane has become more feasible.

Within a new project, we will study both the temporal variation of ^{13}C signature of emitted methane ($\delta^{13}C$-CH_4) in ecosystem and plant community scale, and spatial variation of $\delta^{13}C$-CH_4 in microtopographic scale in a hemiboreal bog ecosystem, Myckelmossen (see Skogaryd station within SITES, www.fieldsites.se), in South-Western Sweden. These will be connected to methane emission measurements conducted at the same bog ecosystem using eddy covariance and automated chamber measurements.

Here we will present the first results of the $\delta^{13}C$-CH_4 measured in ecosystem and plant community scales. The ecosystem scale $\delta^{13}C$-CH_4 was determined using the nocturnal boundary-layer accumulation approach, and the plant community scale $\delta^{13}C$-CH_4 using manual and automated chambers.

Optical synergies for spatiotemporal sensing of scalable ecophysiological traits: SENSECO COST Action CA17134

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Vegetated ecosystems largely mediate terrestrial gas and energy exchange at the atmosphere-biosphere-pedosphere interface. The spatial and temporal acquisition of information on vegetation status and photosynthetic functioning is fundamental to model the dynamic response of vegetation to changing environmental conditions, and therefore necessary for climate change and food security studies. Satellite or airborne Earth Observation (EO) provide the opportunity to collect spatially continuous information of vegetation reflectance at global and ecologically relevant scales. Optical EO is now advancing towards measuring a signal that is emitted by vegetation, i.e. sun-induced chlorophyll fluorescence (F). By flying in tandem with Sentinel-3 (S3), ESA's forthcoming Fluorescence Explorer (FLEX) mission will observe F, which can, in combination with reflectance, provide an indicator of actual photosynthetic activity of vegetation. The FLEX-S3 multi-sensor concept exemplifies the synergistic use of multi-source data to capture scalable ecophysiological traits. This, in combination with other Copernicus missions will allow novel data analytical techniques to be realized. Further combination of these data with proximal sensing measurements from drones and eddy covariance (EC) towers will permit to address critical and still open spatiotemporal scaling questions. The synergistic use, processing and interpretation of data from multiple optical instruments at multiple scales have matured to a stage where harmonization across Europe is now feasible. This has been an incentive for forming a network within recently approved SENSECO COST Action bringing together remote sensing, EC flux tower, and modelling communities. The main aim of the presented SENSECO Action is to ensure that the practices of optical EO measurements of ecophysiology are compatible at various scales, enabling synergistic multi-sensor use and transferability, and to guarantee the transfer and knowledge exchange on scaling methods in a European context. This will be mainly achieved through dedicated expert workshops, training schools and short-term scientific missions.

First mission – towards a global harmonised in-situ data repository for forest biomass datasets validation

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Global measurements of forest height, biomass are urgently needed as essential climate and ecosystem variables. The Forest Observation System – FOS (http://forest-observation-system.net/) is an international cooperation to establish a global in-situ forest biomass database to support earth observation and to encourage investment in relevant field-based observations and science. FOS aims to link the Remote Sensing (RS) community with ecologists who measure forest biomass and estimating biodiversity in the field for a common benefit. The benefit of FOS for the RS community is the partnering of the most established teams and networks that manage permanent forest plots globally; to overcome data sharing issues and introduce a standard biomass data flow from tree level measurement to the plot level aggregation served in the most suitable form for the RS community. Ecologists benefit from the FOS with improved access to global biomass information, data standards, gap identification and potential improved funding opportunities to address the known gaps and deficiencies in the data. FOS closely collaborate with the CTFS-ForestGEO, the ForestPlots.net (incl. RAINFOR, AfriTRON and T-FORCES), AusCover, TmFO and the IIASA network. FOS is an open initiative with other networks and teams most welcome to join. The online database provides open access for: plot location, wood density, canopy height and above ground biomass of trees. Plot size is 0.25 ha or large. The database will be essential for validating and calibrating satellite observations and various models. Comparison of plot biomass data with available global and regional maps (incl. IIASA global biomass map by Kindermann et al., 2013; Boreal and temperate forest by Thurner et al., 2013; NASA tropical by Saatchi et al., 2011; WHRC tropical by Baccini et al., 2012; WUR pan-tropical by Avitabile et al., 2015; IB-CAS global map by Hu et al., 2016) shows wide range of uncertainties associated with biomass estimation.

Interannual mass and energy fluxes in a Mediterranean maquis system

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Despite its ecological role and biodiversity, few studies focused on mass (carbon, water) and energy fluxes in maquis systems. In this work we show the interannual variation of fluxes in a maquis system located in the Mediterranean Basin (Sardinia, Italy). The site is characterized by a significant summer water deficit as revealed by the Bowen ratio indicating a large part of the available energy used for heating air. The decoupling coefficient (DC) showed higher values during winter and spring, indicating that the canopy water vapour flux was decoupled from the atmosphere and that evapotranspiration was mostly controlled by the net radiation. Lower DC values were found during summer (water vapour flux was largely controlled by vegetation). In general, maquis ecosystem was a carbon sink in the first part of the year, while it was a carbon source in the second part. The annual NEE indicates that these systems acts as carbon sink, confirming its potential to mitigate climate change impacts.

ICOS RI presentations

ICOS ATC: From greenhouse atmospheric data collection to model validation

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ICOS is the European based research infrastructure dedicated to the monitoring and improved understanding of carbon sources and sinks. It consists of complementary, harmonized networks of long-term monitoring stations focusing on Europe and adjacent regions including a network of about 40 operational atmospheric stations (measuring atmospheric composition in greenhouse gases and other core parameters). This network is coordinated by the Atmospheric Thematic Center (ATC) that has two main functions: operates the atmospheric data processing chains, which includes data transmission from stations to the routine delivery of near real time quality checked data-stream and carry out regular measurement technology survey, analysis and enable development of new sensors and their testing prior to field deployment within ICOS. The poster will describe recent advances in GHG measurement and data processing together with prospective tasks for the coming years. We will also show the use of near real time processed data to validate GHG atmospheric transport models e.g. Copernicus.

The ICOS Ecosystem Thematic Centre

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Bert Gielen, University of Antwerp, Belgium
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The ICOS National Networks to measure greenhouse gas fluxes over the continental ecosystems are coordinated by the Ecosystem Thematic Centre (ETC), a Central Facility of ICOS RI. The ETC is coordinated and operated by the Euro-Mediterranean Center on Climate Change (CMCC) in collaboration with the University of Tuscia in Viterbo, Italy, the University of Antwerp (Research Centre of Excellence on Plant and Vegetation Ecology) in Belgium and the National Institute for Agricultural Research in Bordeaux, France. The ETC is responsible for the processing of raw data collected by the ecosystem stations on net ecosystem fluxes and its components (CO_2, CH_4, N_2O, H_2O and energy) and meteorological variables. Different processing hierarchies are used for production of the various data sets resulting in different data levels, from Near Real Time to consolidated longer timeseries. Also ancillary information about the sites, e.g. metadata, vegetation and soil characteristics, disturbances and management, are processed centrally at the ETC to ensure high standardization between the different sites, with particular focus on carbon pools and other ecosystem characterization variables (e.g. Green Area Index, trees distribution etc.). The chemical analysis of vegetation

and soil samples are performed in the ETC laboratories in France. The ETC is also responsible for additional services to the network, including assistance to the PIs and the network, development of standards, Instructions and tools and links and collaborations with the other ecosystem regional networks (in Europe and globally).

The ICOS Central Radiocarbon Laboratory (CRL)

Samuel Hammer[1], Johannes Lux[1], Susanne Preunkert[1],[3], Sabine Kühr[1], Eva Gier[1], Ingeborg Levin[2] and the ICOS class 1 station PIs

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Radiocarbon in atmospheric CO2 has successfully proven to be a very powerful tracer for carbon cycle studies and for quantifying CO2 originating from the combustion of fossil fuels. The European Research Infrastructure ICOS has thus selected 14CO2 as one of the key species to be sampled at all atmospheric ICOS class 1 stations and to be analysed at the ICOS Central Radiocarbon Laboratory in Heidelberg. ICOS follows a two-pronged sampling strategy for 14CO2. On the one hand, flask samples will be collected during pre-defined meteorological conditions; on the other hand, continuous, two-weekly integrated samples are collected to estimate long-term trends of fossil fuel CO2 at the sites. Consequently, the CRL processes and measures two different sample types, flasks and high volume integrated samples. The CO2 from flask samples is extracted and transferred to graphite in a dedicated “Extraction and Graphitisation Line” (EGL) with a nominal capacity of 1500 samples per year. The graphite samples are subsequently measured at the CEZA AMS facility in Mannheim, Germany. The high volume samples are extracted from their absorption solution, purified and measured via traditional low level counting in our facilities in Heidelberg.

Apart from a brief introduction to the lab facilities, we present the first results of ICOS integrated high volume 14CO¬2 samples from 12 European stations, starting in 2015. These measurements provide an overview of the current 14CO2 levels at predominantly background stations and illustrate the influence from regional fossil fuel sources at individual stations.

ICOS Belgium Network

Thi Minh Tu Nguyen & Reinhart Ceulemans (National Focal Point)

On behalf of the entire ICOS Belgium Consortium

The Belgian network (ICOS BE) consists of ten observation stations in each of the three ICOS components. ICOS BE is characterized by diverse and unique station locations and synergies with other research infrastructures. The marine component of ICOS BE consists of two multidisciplinary research vessels operating in the North Sea (Simon Stevin and Belgica) and the Thornton buoy which is anchored at the C-Power wind turbine farm. CO2 fluxes between the sea and atmosphere as well as meteorological parameters are continuously monitored. The Simon Stevin is also used in ESFRI LifeWatch. The ecosystem stations of Vielsalm (since 1996) and Brasschaat (since 1997), two of the longest running and most complete flux monitoring stations in the world, add their long-term expertise to the network. The Maasmechelen ecosystem station in the National Park ‘Hoge Kempen’ is the only heather vegetation station currently in ICOS. Three other ecosystem stations are located in an intensive grassland grazed by Belgian Blue heifers (Dorinne), in a short rotation bioenergy plantation of fast growing poplar trees (Lochristi) and at an agricultural site with a four-year rotational crop (Lonzée). Two of the six ecosystem stations (Maasmechelen and Lonzée) are directly linked to AnaEE experimental platforms. The atmospheric observatory on Ile de la Réunion, a collaboration between BIRA-IASB, LSCE (France) and the University of Reunion, is performing near-surface in situ and total column measurements of greenhouse gases for ICOS and the Total Carbon Column Observing Network (TCCON) respectively. Belgium was an active participant in the preparatory phase project in 2011, and one of the founding member countries of ICOS ERIC in 2015. In addition Belgium plays a coordinating role in the ecosystem network - by co-hosting the Ecosystem Thematic Centre - and thus demonstrates that the small country of Belgium is an important player in top international research infrastructures.

Czech Republic: The CzeCOS atmospheric station

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In the Czech Republic ICOS is represented by the Czech Academy of Sciences, namely by the Global Change Research Institute (CzechGlobe) and its research infrastructure CzeCOS (Czech Carbon Observation System).

As for the atmospheric part of ICOS network, measurements are conducted by the Department of Atmospheric Matter Fluxes and Long-range Transport at the Atmospheric Station Křešín u Pacova (AS KRE). The station, including 250 m high guyed mast, was designed and equipped especially for scientific purposes. It is located in central part of the Czech Republic and is part of the National Atmospheric Observatory (NAO) Košetice. Measurements of greenhouse gases has been fully operational since October 2016 and ICOS compliant since April 2017. In May 2018 KRE station was awarded the status of Class 1 ICOS Station. In addition to the monitoring of greenhouse gases, some other measurements are being conducted, such as monitoring of atmospheric aerosols, selected atmospheric pollutants and basic meteorological characteristics. The ongoing measurements are involved in several international programmes.

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ICOS Denmark

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The ICOS National Network of Denmark (ICOS/DK) is a consortium of 4 universities: University of Aarhus, University of Copenhagen, Roskilde University, and the Technical University of Denmark. The financial basis is a 5-year (2016-2021) grant from the Danish Agency for Science and Higher Education and a matching co-financing from the universities.

The network runs 4 main ICOS stations:

- Station Nord (DK-SNO), an atmospheric level 2 station in Northeastern Greenland,
- Zackenberg (GL-ZaF), an ecosystem level 2 station at an arctic fen in Northeastern Greenland

- Voulundgård (DK-Vng), an ecosystem level 1 station at an agricultural field in Jutland,
- Soroe (DK-Sor), an ecosystem level 1 station in a mature beech forest on Zealand.

In addition to these stations we have 7 associated stations, 4 in Greenland and 3 in Denmark. All the ICOS stations in the Danish network build on existing stations that have a longer record (up to 20 years) of flux measurements before ICOS. The present activities concentrate on building the stations up to ICOS standards. The labelling process for the 4 main stations has passed step 1 and step 2 is expected to be concluded during 2019. Labelling of the associated stations will be initiated during 2019.

The home page for ICOS/DK is: http://icos-denmark.dk

ICOS Finland – Observations and key results

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ICOS (Integrated Carbon Observation System) is a European scale distributed infrastructure for on-line, in-situ monitoring of greenhouse gases (GHG). Measurements are based on station networks presently in 12 countries, of which one is ICOS Finland. ICOS Finland has been established by the three national partners – University of Helsinki (UHEL), Finnish Meteorological Institute (FMI), and University of Eastern Finland (UEF), and is currently part of INAR RI (Institute for Atmospheric and Earth System Research Infrastructure).

ICOS Finland network has in total 14 stations, of which four are atmospheric (ATM) stations, four ecosystem (ECO) stations, and six associate ecosystem stations. These stations provide good representatives of boreal and subarctic Eurasian environment in a transition zone from marine to continental climate. Six of the stations are operated by UHEL, seven by FMI, and one is a joint station of UEF and FMI.

Two ICOS Finland stations has been labelled as ICOS compliant stations in November 2017: Hyytiälä ATM station, located in a southern boreal pine forest, and Siikaneva ECO station, representing a southern boreal fen. The labelling process is ongoing at all other ICOS Finland stations. Most of the stations are estimated to get the ICOS label in autumn 2018.

The success of Finnish atmospheric and ecosystem research is largely based on the long-term, comprehensive and continuous data. For example ICOS Finland has the longest methane EC flux record of 13 years from Siikaneva ECO station, and the longest CO_2 EC flux record of 7 years from lake Kuivajärvi ECO associate station.

In the poster presentation we will introduce the latest observations and key results from the ICOS Finland network.

The ICOS French stations network: summary and recent highlights

Lefèvre, Nathalie, Ocean Stations network, IRD, UMR LOCEAN, France, Delmotte, Marc, Atmospheric Stations network, CNRS, UMR LSCE, France, Ramonet, Michel, Atmospheric Stations network, CNRS, UMR LSCE, France, Dufrêne, Eric, Ecosystem Stations Network, CNRS, UMR ESE, France, Lafont, Sébastien, Ecosystem Stations network, INRA, UMR ISPA, France, Loustau, Denis, French Focal Point, INRA, UMR ISPA, France.

The French ICOS stations network covers the three reservoirs of the carbon fast cycle, the atmosphere, land surface and ocean. Each includes ICOS stations officially labelled by the ICOS-RI and additional stations. The community involved comprises 80 scientists belonging to 12 Research Institutes and 21 Universities in metropolitan France, La Réunion Island, French Guyana, Bolivia, Ivory Coast, Greece and Ireland. The French NN is partly inherited from European projects started with the Euroflux project in 1996 and partly composed of new stations created recently for optimising the coverage and performances of measurements in the three domains. The French ICOS NN is being coordinated with major ESFRI RI in environment (ACTRIS, ANAEE, e-LTER).

• The atmospheric network is distributed over Europe, Africa, Antarctica and South America and comprises 15 stations among which two class-1 and two class-2 ICOS stations. It has developed new, efficient and low cost technique for sampling the GHG profiles in the atmospheric column (Aircores). Atmospheric data showed recently that mercury (Hg) and CO2 deposition over continental surfaces are correlated and evidenced the role of the vegetation in the seasonal variations of Hg atmospheric concentration (Jiskra et al. 2018).

• The Ecosystem network includes 17 ICOS stations (4 class-1, 7 class-2 and 6 associated) covering temperate mires (1), alpine grasslands (2), temperate grasslands (2), croplands (4), temperate forests (4), Mediterranean forests (2) and tropical forests (2).

• The ocean network includes 17 stations distributed in the Atlantic, Indian and Southern oceans and Mediterranean Sea among which the France-Brazil line is a class-1 ICOS station. These stations contribute to the SOCAT and OCADS databases. The French Ocean network highlighted recently the impact of Amazon plume sink and the effects of anomalous sea temperature variations on the Atlantic CO2 exchanges (Ibanhez et al., 2016, 2017).

Towards integrating greenhouse gas observations from land, ocean and atmosphere – National Network contribution from ICOS Germany

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ICOS Germany records scientifically reliable and consistent high-quality datasets of greenhouse gas concentrations and fluxes and aims for an evaluation and verification of emission reduction measures. In the long term, ICOS Germany strives for the opportunity to review the effectiveness of policies to reduce greenhouse gas emissions and to assess carbon storage in the ocean and in terrestrial ecosystems. The station network currently consists of 9 atmospheric, 15 ecosystem, and 5 ocean stations. Beside these measurement stations, ICOS Germany operates 2 Central Facilities (see separate abstract and poster), i.e. the Flask and Calibration Laboratory (FCL) and the Central Radiocarbon Laboratory (CRL).

The Atmosphere Programme is setting up further instrumentation on tall towers and ensures the continuation of the already operational sites with Hohenpeissenberg (DE-HPB) and Gartow (DE-GAT) already being labelled as official ICOS stations. Data collection, data analysis and near-real-time data delivery (NRT) has been automated for the existing stations. Based on these data, inverse modelling now enables high-quality data products to be generated.

The Ocean Network includes 3 observing ships and 2 time series stations to quantify oceanic sources and sinks of CO_2, its ^{13}C-isotopy, other greenhouse gases as well as biogeochemical and physical properties. The ships are regularly in use on a transatlantic route, on the Baltic Sea and in the Southern and Arctic Ocean.

The 2 time series stations, CVOO and Hausgarten, are located on the Cape Verde Islands and in the Fram Strait between Greenland and Spitsbergen, respectively.

The 15 ecosystem stations continuously measure the exchange of trace gases between the land surface and the atmosphere. The station distribution followed a cluster approach with the sites being mainly geographically pooled to represent different climatic regions. At many sites, long-term records were already available, covering past extremes and disturbances. The currently monitored land uses include forest (5x), grassland (5x), cropland (3x), and forested areas on peatland (2x). Management activities that form major impacts on the carbon cycle such as fertilization, harvest or other biomass removal are also being recorded at each site.

Regarding already obtained data from all 3 domains, the value and importance of continuous observations becomes clear. Only long-term measurements can be used to estimate trends, to produce reliable forecasts and to differentiate between climate – such as the current 2018 drought and heat wave in Europe – and management-driven impacts on regional greenhouse gas balances.

ICOS-Italy Network: strategies and perspectives

Carlo Calfapietra on behalf of the entire network*

The international scientific community has shown that in the different compartments (atmosphere, terrestrial ecosystems and ocean, just to consider the ICOS target) the impacts, the responses and the mitigation capacity could be different from what assumed so far. For example, a significant impact of climate change on the biodiversity of natural ecosystems and/or on the productivity of agro-ecosystems can be assumed. In Italy, this problem appears particularly important given the multiplicity and diversity of ecosystems, the circulation of air masses and seas in the various climatic zones and the vulnerability of most of them.

The establishment of the ICOS-Italy Joint Research Unit, coordinated by the National Research Council (CNR) and including a total of 16 institutions, allows to develop joint interdisciplinary activities with the aim of creating an Italian ICOS node strong, active and coordinated, able to actively contribute to promote Italian participation in ICOS-ERIC.

Italian network includes a number of ecosystem, atmospheric and marine station which are characterized by enormous differences in climatic and environmental conditions going from the Alps to the Southern island of Lampedusa. In the following years thanks to the project “Upgrading ICOS-Italy Observation Network in the Mediterranean” Pa (PRO-ICOS_MED) a lot of stations, especially those based in the South of Italy, will be upgraded with state-of the art instrumentations and with the aim to link ICOS protocols with advanced related measurements in line with the ICOS 2.0 strategic view.

As an example Lampedusa station the most southern station of ICOS, actually included among the atmospheric stations, will be implemented with the marine and ecosystem stations, representing the only station with the three components in the same area.

Netherlands: The Ruisdael Observatory and ICOS: A surface-atmosphere research Infrastructure in The Netherlands 2018 – 2027

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A consortium of 10 Dutch institutes have started this year with the construction of a distributed atmospheric observatory. The observatory will focus on clouds, air quality, GHG and their interactions. The Ruisdael Observatory will consist of: 1) four advanced anchor stations: the already existing, grassland site Cabauw, the forest site Loobos, the land-sea transition site Lutjewad, and a new urban station in the Randstad agglomeration; 2) a number of mobile and airborne facilities to probe the physical and chemical state of the atmosphere; and 3) a computational facility for real-time assimilation of the observations into high-resolution atmospheric models (DALES).

The Ruisdael Observatory will, among others, facilitate a breakthrough in providing emission estimates of greenhouse (CO2, but also CH4 and N2O) and other gases at unprecedented accuracy and spatial resolution. While this observational dataset by itself already facilitates quantification of emissions, the coupling to a powerful data assimilation infrastructure using novel biogeochemical modelling approaches will bring the real breakthrough. We will be able to obtain reliable emission estimates on the regional and national scale, for example, urban dome of Rotterdam or the Dutch Randstad as a whole. This scientific breakthrough occurs at the intersection of big data (e.g., the real-time need for terabytes of distributed data), computer science, atmospheric science and society, while linking the three focus areas forcers, feedbacks and forecasts.

Because Ruisdael combines the Dutch contributions to both ICOS and ACTRIS, we are in a unique position to study GHG exchange and weather interactively. For example, the facility will enable to better understand cloud formation and aerosol dynamics and their short-term feedback on GHG exchange, all set in the complex mixed agricultural-urban delta landscape of The Netherlands, serving as an example to similar regions elsewhere.

ICOS Switzerland – Greenhouse gas stories from high altitudes

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ICOS Switzerland (ICOS-CH) is the Swiss contribution to the Integrated Carbon Observation System Research Infrastructure (ICOS RI). The ICOS-CH consortium consists of ETH Zurich (National Focal Point), Empa, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, University of Bern, University of Basel and MeteoSwiss. ICOS-CH is part of ICOS RI with two sites located in the Swiss Alps, one atmospheric site (Jungfraujoch, 3580 m asl) and one ecosystem site (Davos, 1639 m asl). Both sites are unique in terms of their geographical location, site history and relevance for national and international research. JFJ is the highest, permanently manned research station within Europe. Next to the measurements of concentrations of all major greenhouse gases, unique continuous perennial data at JFJ are also available for the isotopic composition of CO2 and O2. Davos is the only subalpine spruce forest (1639 m asl) within ICOS RI and is one of the oldest ecosystem flux sites globally (eddy covariance measurements since 1997). Jungfraujoch was officially certified as Class 1 ICOS station in May 2018, while Davos is candidate Class 1 station and currently in step 2 of the labelling process.

In 2017, ICOS-CH has successfully received funding from the Swiss National Foundation for the next project phase (2017-2021). In the same year, the ICOS-CH Annual Meeting was for the first time linked to the Swiss Geoscience Meeting where dissemination of scientific results took place within an ICOS-dedicated session. The ICOScapes campaign visited JFJ in March 2018. For Davos, a custom-made virtual reality tour is in regular use for outreach purposes since 2017.

ICOS UK Network

Jessica Thorn (Project Co-ordinator) and Prof. Andrew Watson (Focal Point)

On behalf of the entire ICOS UK Consortium

The UK-ICOS community consists of five stations from the observing systems (Ocean, Atmospheric and Ecosystems) and constitute the UK-ICOS Research Infrastructure. The key UK sites in ICOS include: the Porcupine Abyssal Plain (PAP) sustained ocean observatory run by the NOC and the MET Office; The UK-Caribbean VOS line, run by the University of Exeter and the National Oceanography Centre; the Western Channel Observatory, run by the Plymouth Marine Laboratory; the Auchencorth Moss ecosystem station, run by the Centre for Ecology and Hydrology; and the Weybourne Atmospheric Observatory, run by the National Centre for Atmospheric Science and the University of East Anglia. The PAP sustained ocean observatory is situated in the subpolar Northeast Atlantic at a water depth of 4800 metres, and is the longest running multidisciplinary open-ocean time series observatory in Europe and one of the longest in the world. The PAP SO has become a major focus for international and interdisciplinary scientific research including water column biogeochemistry, physics and benthic biology. The Oceans and Atmospheric Science Group based at the University of Exeter specializes in taking high precision measurements of carbon (dissolved inorganic carbon and total alkalinity), methane, nitrous oxide and tracer gases in the oceans and atmosphere and undertake regular expeditions along the UK-Caribbean line, using voluntary observing ships, to take regular samples across a repeat line in the North Atlantic Ocean. The Western Channel Observatory is an oceanographic time-series and marine biodiversity reference site situated in the Western English Channel. On a regular basis, in situ measurements are taken at coastal station L4 and also at the open shelf station E1 using the research vessels of the Plymouth Marine Laboratory. The measurements taken are complemented by PML's excellence in ecosystem modelling and satellite remote sensing science. Auchencorth Moss is part of a sensitive peatland ecosystem in central southern Scotland. It is a valuable location for long-term monitoring of surface/atmosphere exchange fluctuations and measurements indicating environmental change. The large number of parameters measured at the site is part of a wide range of monitoring networks and is also used in collaborative work with the wider scientific community. Measurements collected cover a wide range of environmental variables including carbon catchment studies, surface/atmosphere exchange fluxes, real-time measurements of aerosol composition and reactive gases and meteorological variables. Measurements taken at the site contribute to national and international records. The Weybourne Atmospheric Observatory (WAO) is a Global Atmospheric Watch (GAW) Regional station located on the North Norfolk Coast, UK. The WAO take continuous measurements of ozone, as part of the DEFRA network, and basic meteorological parameters. They also collect high-precision long-term in situ measurements of atmospheric carbon dioxide (CO_2), oxygen (O_2), carbon monoxide (CO) and molecular hydrogen (H_2), atmospheric methane (CH_4), nitrous oxide (N_2O) and sulphur hexafluoride (SF_6).