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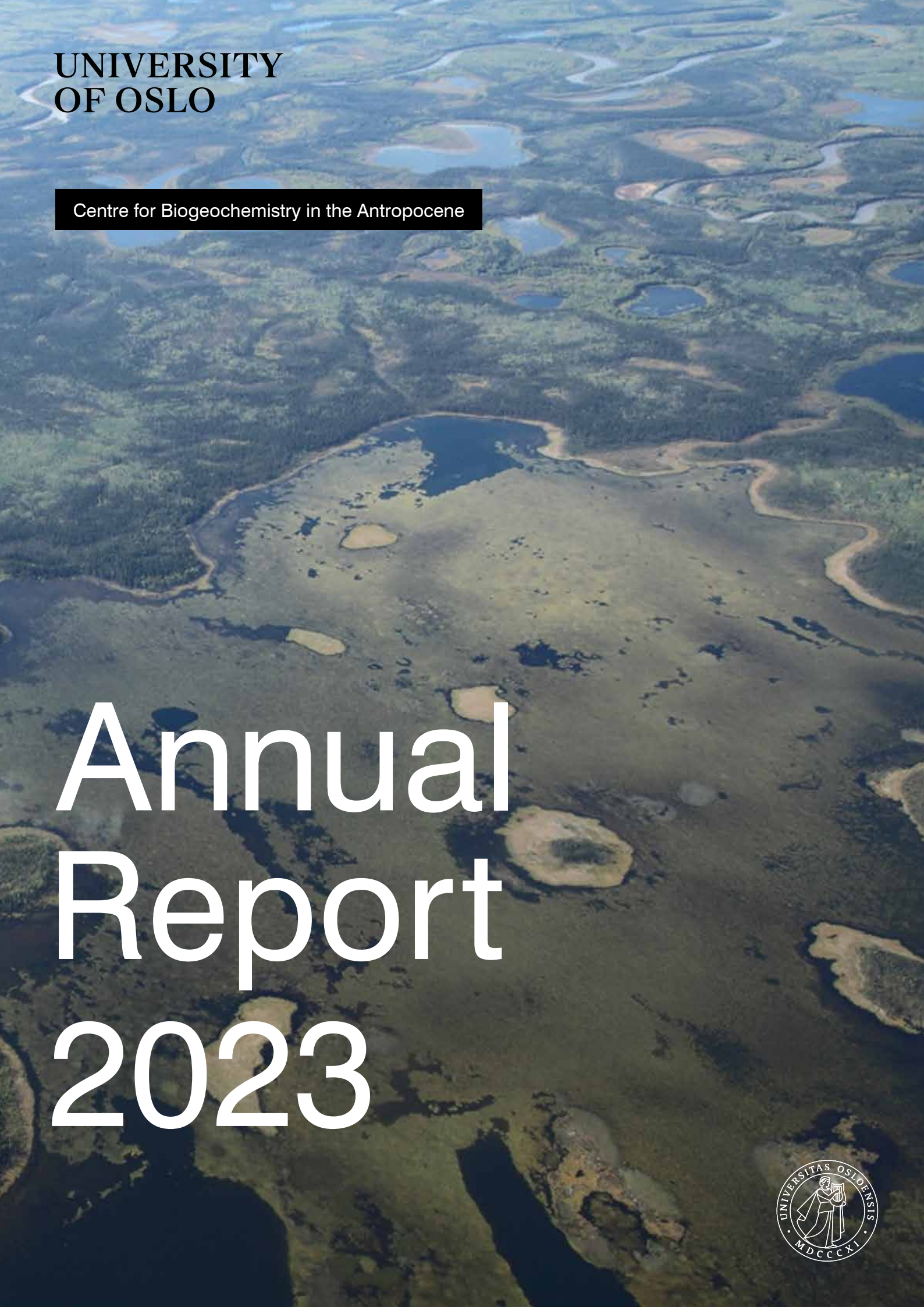
Centre for Biogeochemistry in the Antropocene

Annual Report 2023



We study interactions and feedbacks between climate, carbon cycling and ecosystems in northern latitudes.

Photo: Getty Images

Contents

6 Introduction

Mission, vision and values 6
CBA research topics 8
Management structure 10
CBA status and highlights 2022 13

15 Special focus

Tipping Points report presented at the COP28-meetingt 16
Marine food webs and antimicrobial resistance spread will be studied in the newly RCN funded IMPACT project 20
New ERC Starting Grant within CBA 22

25 Research

Micro- and Nanoplastics in the Atmosphere 26
Hot ponds in subarctic Norway are hotspots of methane emissions 28
Thicker snow and increased runoff combine to trigger permafrost collapse on Svalbard 32
MIMICS+: A new microbial model for decomposition of organic matter in soil 36
Mongolian field work photo essay: Permafrost4life 40
Finnmark field work photo essay 44
How do dwarf shrubs contribute to carbon capture? 46

49 Outreach

Chronicles and popular science 50
Book 51

53 CBA events

CBA events 54
Internal CBA events 56

59 Education

65 Publications

70 CBA's economy in short

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Mission

We study interactions and feedbacks between climate, carbon cycling and ecosystem in northern latitudes. We assess and predict links from atmosphere to terrestrial and aquatic systems for carbon and other key elements, and feedback to climate by greenhouse gas productions in ecosystems. This is crucial for improvement of Earth system models, and thus to predict and counter anthropogenic climate change.

We educate the next generation of climate scientists in the fields of bioscience, chemistry and geoscience. We engage the public to implement strategies that help society and ecosystems reverse or adapt to climate and environmental changes.

Vision

Our shared vision is

- to develop and deploy basic science and novel approaches to understand biogeochemical cycles in a changing anthropogenic world.
- to educate students and raise awareness in society at large about the links between climate and ecosystem processes for the better of the future.

Values

We want to achieve excellence through

- Scientific rigorousness and openness
- Ethical practices in all areas of our endeavor
- Scientific accountability
- Respect, professionalism and dedication
- Sense of responsibility to transfer knowledge to the public
- Sharing of best practices and working as a team

CBA research topics

Faculty staff, postdocs and PhDs

Weathering processes and soil characterization

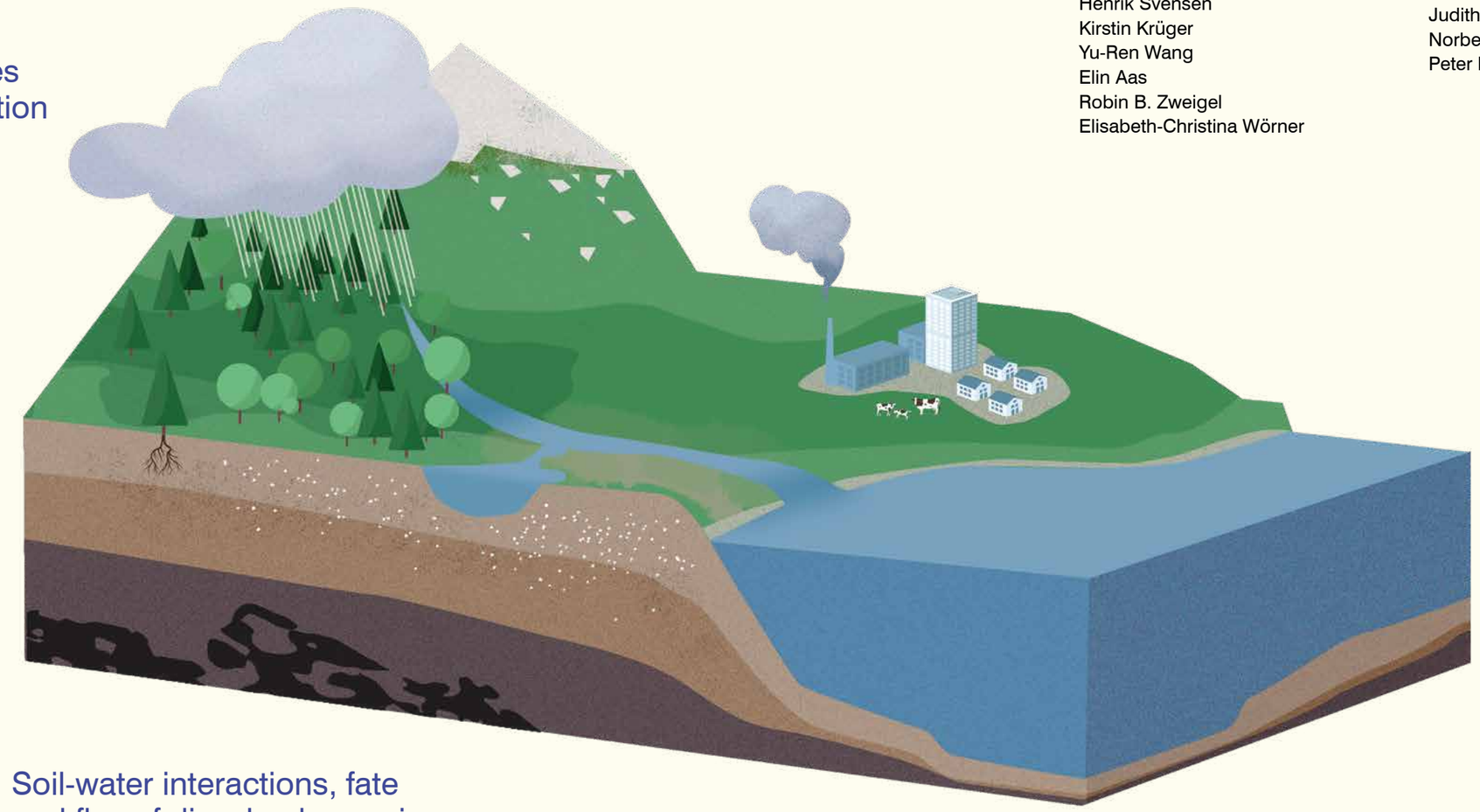
Helge Hellevang
Mats Rouven Ippach

Microbial genomics and metabolism

Alexander Eiler
Jing Wei
Laurent Fontaine
Eira Carlsen
Franck Lejzerowicz
Peter Dörsch
Inger Skrede

Atmospheric chemistry

Armin Wisthaler
Tomas Mikoviny
Baptiste Languille
Felix M. Piel
Wojciech Wojnowski
Anjitha S. K. Geetha
Alexander Håland
Claus J. Nielsen
Niels Højmark Andersen



Soil-water interactions, fate and flux of dissolved organic matter and key elements

Heleen de Wit
Andrea Popp
Nicolas V. Parra
Jacqueline Knutson
Camille Crapart
Yu Yu
Francois Clayer
Xiang Lu

Climatic change and feedbacks

Terje K. Berntsen
Trude Storelvmo
Frode Stordal
Lena M. Tallaksen
Anders Bryn
Yeliz Yilmaz
Henrik Svensen
Kirstin Krüger
Yu-Ren Wang
Elin Aas
Robin B. Zweigel
Elisabeth-Christina Wörner

Permafrost dynamics, thaw, age, fate and flux of "old carbon"

Sebastian Westermann
Frans-Jan Parmentier
Jon Petter Omtvedt
Jing Wei
Alexander Eiler
Juditha Aga
Norbert Pirk
Peter Dörsch

Contaminants and carbon in coastal ecosystems

Katrine Borgå
Tom Andersen
Dag O. Hessen
Jan David Heuschele
Heidi Sjursen Konestabo
Sabrina Schultze
Alexander Eiler
Franck Lejzerowicz

Freshwater and coastal ecosystem responses

Dag O. Hessen
Tom Andersen
Elisabeth Alve
Aleksandr Berezovski

CLIPT lab

Alexander Eiler
Tom Andersen

Phytotron Lab

Ane Vollsnes
William Hagopian

ECODISTURB

Christina Nadeau
Dag O. Hessen
Manjana Milkoreit

Management structure

CBA is a joint operation between the Department of Biosciences, Geosciences, and Chemistry. This important interdisciplinary element of our centre is reflected in both the leader group and the board.

CBA members at the Annual Meeting in Drøbak

Participants in alphabetic order:
→

Aleksandr Berezovski
Alexander Eiler
Armin Wisthaler
Camille Crapart
Christina Nadeau
Dag Olav Hessen
Eira Carlsen
Elin Cecilie Ristorp Aas
Elisabeth-Christine Worner
Franck Lejzerowicz
Francois Clayer
Frans-Jan Parmentier
Heleen de Wit
Jacqueline Knutson
Mats Ippach
Nikita Sobolev
Norbert Pirk
Peter Dörsch
Rolf David Vogt
Sebastian Westermann
Sigrid Trier Kjær
Siyan Li
Terje Berntsen
Thomas Rohrlack
Tom Andersen
Xiang Lu

The leader group

Sebastian Westermann
Professor in geosciences and centre leader

Alexander Eiler
Professor in biology and centre leader

Dag O. Hessen
Professor in biology

Eira Carlsen
ECR representant

Terje Koren Berntsen
Professor in geosciences

Armin Wisthaler
Professor of atmospheric chemistry, Department of Chemistry

Manon Bajard
Centre coordinator

The board

Bjørn Jamtveit
Vice Dean (Prodekan) of Research

Einar Uggerud
Head of Department of Chemistry

Bernd Etzelmüller
Head of Department of Geosciences

Melinka Alonso Butenko
Acting Head of Department of Biosciences

The scientific advisory group

Tim Lenton
University of Exeter, Global Systems Institute

Vigdis Vandvik
Bjerknes Centre for Climate Research, University of Bergen

Marten Scheffer
Wageningen University & Research

CBA status and highlights 2023

Sebastian Westermann and Alexander Eiler
Centre co-leaders

The past year has been a period of growth and collaboration for the Centre for Biogeochemistry in the Anthropocene (CBA). We have stepped into the role of Centre leaders in 2023, with the plan to alternate between lead and co-lead each year. We take over from Dag Hessen whose leadership has been instrumental in establishing CBA and who has led the center during five years of constant growth. Tusen takk for your successful work, Dag, and we are happy that you will continue to be a leading voice in CBA in the coming years! We would also like to thank Manon Bajard and Emma Wall, who have administered the centre with dedication and skill in the past year, for their invaluable work.

CBA is a distributed Centre with researchers located in different buildings, which presents both opportunities and challenges. Our collaboration and communication have grown stronger over the past year, and we are increasingly working together across different physical locations. In October 2023, we held our annual meeting in Drøbak and Ås, where we had the opportunity to visit our partners at NMBU and engage in meaningful discussions about the future direction of CBA. It was inspiring to see the active participation of researchers at all career stages in these discussions, further shaping the vision of our Centre in a truly bottom-up approach. We especially welcome the dedication and enthusiasm of young scientists who have established an early career researcher network within CBA to connect, exchange ideas, and collaborate across the various buildings and disciplines.

One of the key projects that has been a focus for CBA this year is BioGov, which involves PhD students from different institutes working closely together. This project is a testament to the collaborative spirit and interdisciplinary approach that are at the heart of CBA's mission. We are also proud to highlight the successful funding of the ERC project ACTIVATE, developed and led by Norbert Pirk. This project addresses a fundamental gap in our understanding of the Earth system by aiming to develop a methodology to obtain representative estimates of land-atmosphere exchanges of carbon, water, and energy. This project is a significant achievement within CBA and we are excited to see the impact it will have in the field of biogeochemistry.

Since its start in 2018, CBA has evolved into a strong network, with active engagement not only from the University of Oslo, but also from our partners at for example NMBU and NIVA. We are grateful for the opportunity to lead this dynamic and innovative Centre – a big thanks to all our researchers, partners, and supporters for your ongoing dedication and commitment to biogeochemistry research!

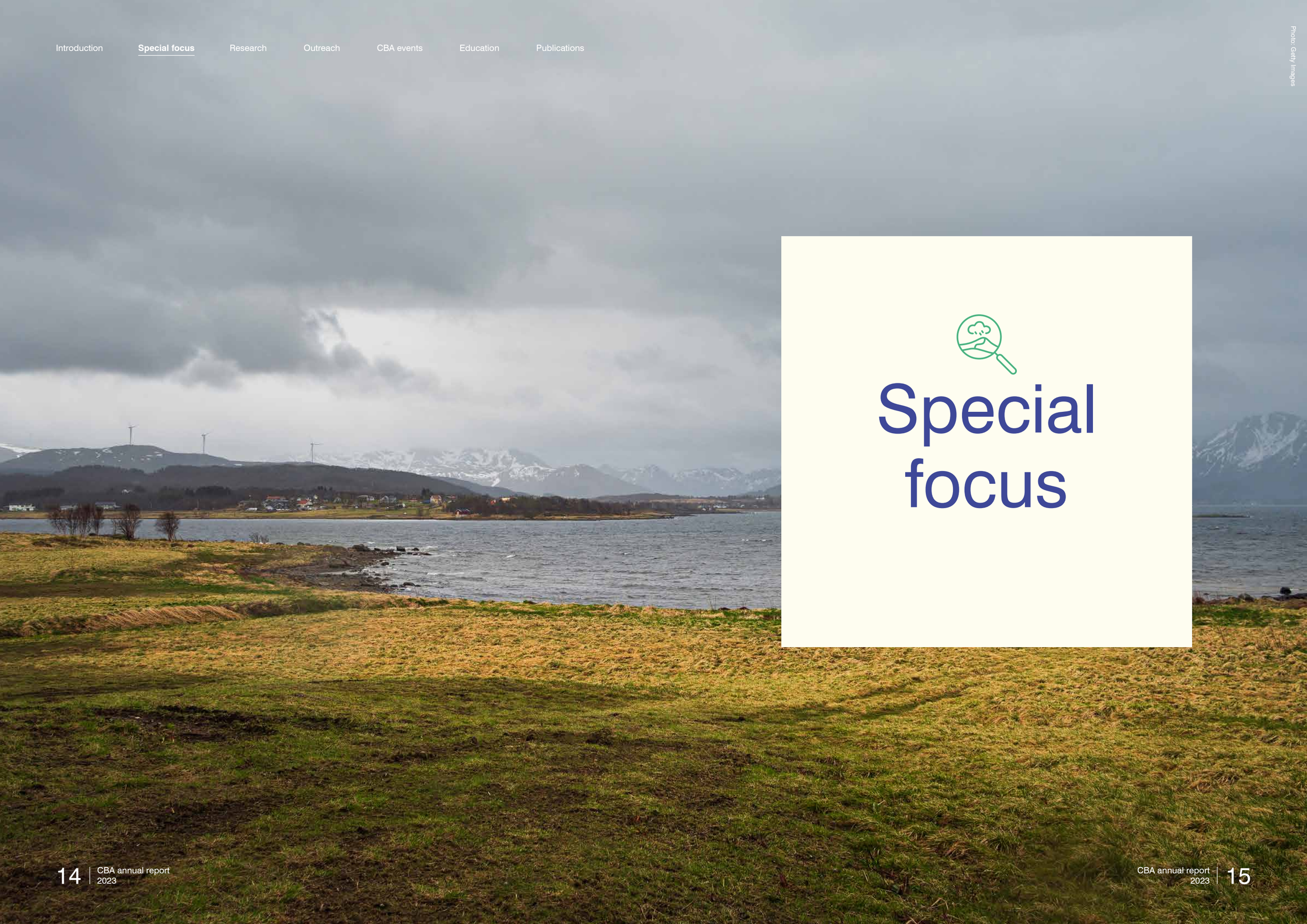


Photo: Getty Images

Special focus

Tipping Points report presented at the COP28-meeting

Dag Olav Hessen
Professor, Department of Biosciences

Tipping points has become a widespread concept describing non-linear, often abrupt system changes in systems, primarily related to climate induced changes in earth system.

A key property of tipping points is that some stressor (e.g. warming) push the system towards a threshold resulting in non-linear changes that are irreversible on human timescales (Lenton et al., 2008; Steffen et al., 2018, Armstrong McKay et al., 2022). Tipping point are also in the strict sense characterized by self-propelling, positive feedbacks, meaning that initial changes will be the starting point of cascading, positive feedbacks towards the tipping point. There is some evidence that multiple climate tipping points may be triggered within the temperature target range set by The Paris Agreement: 1.5°C to well below 2°C (Armstrong McKay et al., 2022; Wunderling et al., 2023). Since 1.5 °C now seem unavoidable, and temperatures may approach 3.0 °C by the end of the century unless unprecedented actions are taken (WMO, 2023), climate tipping points add new arguments for the urgency of more ambitious climate action and urgency.

Several CBA-affiliated persons have been involved in a following up report on climate tipping points at many levels, including those in global systems, but also the potential for positive tipping points in governance, economy, technology, norms and the society at large to prevent or minimize the risk of the dangerous tipping points lurking ahead. During 2023 an international group, using the tipping point paper by Armstrong McKay et al. (2022) as a point of departure, elaborated further on potential climate induced tipping points identified in this (and previous papers) in systems such as the Amazon rainforest, coral reefs, the Greenland ice plus Arctic as well as west- and east-Antarctic ice sheets, permafrost, boreal forest, the North Atlantic Circulation. Estimated temperature thresholds for onset of tipping points were scrutinized and updated. In addition, new systems were added to the list, and not the least were social and political drivers and potential tipping points "in the right direction" identified.

The final report was presented at the COP28 meeting in Dubay January 2024 and received substantial media coverage. The report (*https://global-tipping-points.org*) states initially that "Harmful tipping points in the natural world pose some of the gravest threats faced by humanity. Their triggering will severely damage our planet's life-support systems and threaten the stability of our societies". The extensive report consists of four main sections; 1: Earth system tipping points, 2: Tipping point impacts, 3: Governance of Earth System Tipping points and 4: Positive tipping points in technology, society and economy. Section 3 was led by Manjana Milkoreit, who also presented this part of the report at the COP28 meeting in Dubai. Also, Christina Nadeau and Dag Hessen was involved in the report, and the chapter on tipping points in global freshwater ecosystems was led by Hessen. Several of the topics are currently extended and will appear as full papers in a special issue of Earth System Dynamics.

The chapter on freshwater relates directly to several of the ongoing activities at CBA, elaborating how eutrophication and browning may entail internal nutrient cycling, promoting anoxia and thereby outgassing of CO_2

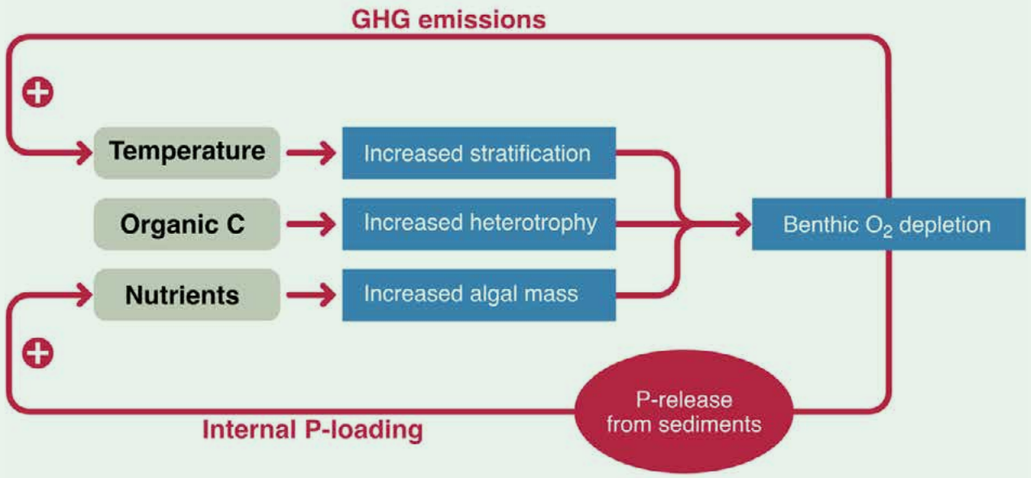


Figure 1: Positive feedbacks in lakes linked to eutrophication and browning. Benthic anoxia and for eutrophic lakes also release of phosphorus serves as a tipping points.

Figure 2: Permafrost ponds at the Yukon Flats.
Photo: Sebastian Westermann

and CH_4. This will well thus technical be a self-propelling "positive feedback", but with negative impacts by constituting a significant source of greenhouse gases to the atmosphere (Figure 1). Also, the appearance or loss of ponds and lakes residing on permafrost (Figure 2) are candidates for non-linear changes or binary shifts (presence vs absence) with major impacts on GHG-emissions from the tundra biome. Other candidates for abrupt shift when thresholds are passed are salinization and species immigration.

There are several initiatives underway for following up of how non-linear ecosystem responses at large scales may happen, and for some of these climate and nature degradation are mutually driving the system towards a potential tipping point (e.g. Amazonas).

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"Permafrost thaw is not just a future risk – it is happening now, releasing carbon stored for millennia and accelerating climate change"

Marine food webs and antimicrobial resistance spread will be studied in the newly RCN funded IMPACT project

Alexander Eiler
Professor, Department of Biosciences

&

Even Werner
PhD student, Department of Biosciences

Residues from human activities, such as wastewater treatment plants and aquaculture, introduce active antibiotic compounds into marine environments. These compounds, combined with metal residues and anthropogenic surfaces can facilitate horizontal gene transfer of antibiotic resistance genes. Human and animal-associated bacteria carrying antimicrobial resistance genes (AMRGs) are alarmingly prevalent in many coastal areas due to anthropogenic activities. The IMPACT project is on a mission to investigate hotspots of AMRGs and gene transfer in marine waters, aiming to unravel the complexities of AMRG spread in nature.

A Comparative Approach Across Oceans: Indonesia and Norway

The IMPACT project adopts a comparative approach, focusing on two vastly different countries: Indonesia and Norway. These nations face unique challenges regarding AMRGs. Norway, with its modern wastewater treatment systems and regulated antibiotic use, still struggles with the release of harmful agents and their potential integration into the human food chain through mariculture and fisheries. In contrast, Indonesia treats only a small percentage of its wastewater and has different practices regarding antibiotic usage, and thus threats of AMRG spread back to humans.

Assessing the Impact on Marine Life and Human Health

By comparing levels of metals, antibiotic residues, and marine microbiomes with measures of AMRG presence, the project aims to assess the potential harm to human health. Using the microbiome of blue mussels and popular fish species as models, we will study AMRGs in various marine environments, including recreational, sewage-impacted, and pristine areas.

Relevance and Potential Outcomes

The findings of the IMPACT project will reshape our understanding of marine food webs and their role in the spread of AMRGs. If marine life is found to promote the uptake of resistance genes and the spread of pathogenic bacteria, it highlights an urgent need to prevent such dissemination. This project emphasizes the necessity to consider the unique conditions of developing countries concerning antibiotic usage, pollution, and aquaculture practices. Local actions to prevent recreation in contaminated areas could be a direct outcome, as well as broader strategies to safeguard human health.

A Call to Action for Multiple Stakeholders

The IMPACT project aims to influence wastewater treatment companies, the aquaculture industry, authorities, and the public to recognize and address the threat posed by the convergence of multiple AMRG drivers. By treating this issue as a significant threat to human health, we can develop strategies to prevent the spread of antimicrobial resistance and protect our marine ecosystems and food sources.

Figure 1: Marine food webs can act as reservoirs for antimicrobial resistance genes (AMRGs), allowing resistant bacteria to spread through fish and seafood to humans. Photo: Even Werner

New ERC Starting Grant within CBA

Norbert Pirk
Researcher, Department of Geosciences

&

Sebastian Westermann
Professor, Department of Geosciences

&

Terje Berntsen
Professor, Department of Geosciences

While land-atmosphere exchanges of carbon, water, and energy are key to understanding changes in the Earth system, we still fundamentally lack a methodology to obtain representative estimates of these surface fluxes at the scale of a single grid cell of an Earth System Model (typically 10–100 km), let alone for a wider region. To address this issue, the European Research Council funded a new project entitled "Actively learning experimental designs in terrestrial climate science (ACTIVATE)". ACTIVATE combines an observing system consisting of a swarm of drones carrying meteorological sensors and gas analyzers, mobile and stationary flux towers, as well as satellites, and fuses their observations with different land-atmosphere models using data assimilation methods. ACTIVATE aims to develop an adaptive Bayesian Experimental Design framework to generate maximally informative observation strategies for expensive data collection, and adaptively reposition drone swarms during a flight as new observations become available to optimally infer surface fluxes in the landscape.

The plan is to demonstrate the framework in idealized synthetic experiments, at managed and industrial sites with known flux hotspots, and in targeted high-resolution simulations in poorly represented regions with expensive models that explicitly resolve subgrid-scale processes in Earth System models. We will apply the ACTIVATE framework around existing observatories in vulnerable arctic regions, where the lack of strong observational constraints from state-of-the-art observing systems is particularly apparent and problematic. ACTIVATE aims to produce unprecedented observational datasets for new model developments in some of the most data-sparse regions on Earth, uncertainty-aware parameter estimates for critically unconstrained processes, and a pioneering adaptive experimental design framework for terrestrial observing systems. The broader vision of ACTIVATE is to develop active learning capabilities for improved data assimilation in models to elevate our understanding of land- atmosphere interactions across spatio-temporal scales.

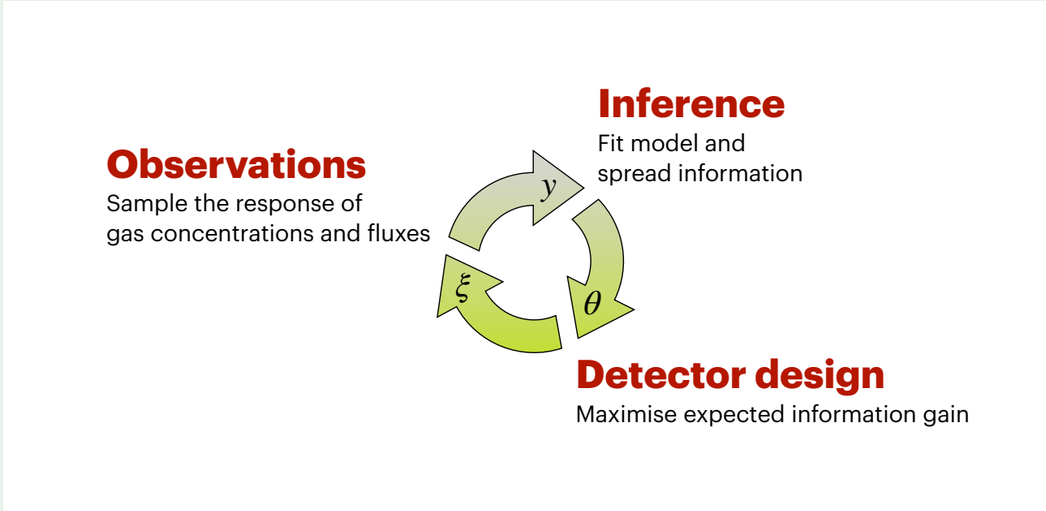

Figure 1: The adaptive Bayesian Experimental Design concept gives a formal framework of active inference to, on the one hand, optimize experiments in order to make them as informative as possible about a given process, and on the other hand, understand the decision-making process. Starting with an initial experimental design **ξ** (the formal description of where and when to sample), observations **y** are obtained. In the context of ACTIVATE, we think of our observing system as a swarm of drones, manual flux chambers, a network of EC towers (e.g., FluxNet), polar orbiting satellites, or a combination of these sensors. These observations **y** are combined with the forward model, namely a chosen representation of biogeochemistry that is coupled to an observation model (such as a turbulence-resolving wind model for drone-based concentrations) in the inference step. Posterior parameter distributions are estimated using probability density functions, as $p(\boldsymbol{\theta}|\mathbf{y}, \boldsymbol{\xi}) \sim p(\boldsymbol{\theta})\, p(\mathbf{y}|\, \boldsymbol{\theta}, \boldsymbol{\xi})$, where **θ** denotes the uncertain target parameters we wish to infer. Here, sampling the likelihood term $p(\mathbf{y}|\, \boldsymbol{\theta}, \boldsymbol{\xi})$ typically requires running the forward model hundreds of times, making it the computationally expensive part of the loop. This inference step formalizes the learning about model parameters and has the potential to spread the information obtained by the observations in space and time.

Figure 2: Current detector hardware, operated by the DroneLab core facility at the Department of Geosciences. Left: Commercial vertical-takeoff-and-landing drone “Trinity F90” with meteorological sensors tested near the Zackenberg Ecological Research Station, North-East Greenland, in August 2022. Right: “UiO-Flamingo” multi-copter drones for swarm applications at a test site near Oslo.

Photo: Getty Images

Research

Micro- and Nanoplastics in the Atmosphere

Nikita Sobolev
Postdoctoral Research Fellow, Department of Chemistry
&
Keerthana Balashankar
Master's Student, Department
Felix Benjamin Blixt Hasle
Master's Student, Department of Chemistry
Niels Højmark Andersen
Senior Engineer, Department of Chemistry
Tomas Mikoviny
Senior Engineer, Department of Chemistry
Armin Wisthaler
Professor, Department of Chemistry

Humanity faces many sustainability challenges, but the release of large amounts of long-lived deleterious substances into the environment stands out as the most pressing issue. The emission of large amounts of carbon dioxide (CO_2) into the atmosphere is of course the most prominent example, but another problem has recently raised major scientific and public attention: the release and accumulation of large amounts of synthetic organic polymers -commonly termed 'plastics'- into the environment.

Current estimates assume that about 5 gigatons (Gt) of synthetic organic polymers have accumulated in the environment since large-scale production started in the 1950ies. Once released into the environment, synthetic organic polymers do not (or very slowly) decompose chemically or biologically, but continually fragment into smaller and smaller pieces, ultimately forming micrometer-sized particles ('*microplastics*', MP) or even nanometer-sized particles ('*nanoplastics*', NP). MP have been ubiquitously found in aquatic and terrestrial environments. A series of recent highly regarded studies (*e.g., Evangeliou et al., 2020*) have concluded that the atmosphere acts as a major reservoir and transport medium for plastics particles, but the observational evidence remains scarce. This is primarily owned to the fact that it is currently not possible to quantify the amount of MP and NP that resides in the atmosphere.

In 2023, the Research Council of Norway funded the three-year project "*Airborne Microplastic Detection, Origin, Transport and Global Radiative Impact*" (MAGIC) led by Dr. Nikolaos Evangelios from NILU. The research group of Prof. Armin Wisthaler at the Department of Chemistry joined the MAGIC research consortium to develop a new chemical-analytical tool for the quantitative detection of atmospheric plastics particles. Prof. Wisthaler's group is world-leading in the application of proton-transfer-reaction mass spectrometry (PTR-MS) to challenging measurement tasks. A photograph of the PTR-MS analyzer that is currently used in the MAGIC project is shown in Figure 1. PTR-MS measurements are complemented by μRaman spectroscopy measurements, also carried out at the Department of Chemistry.

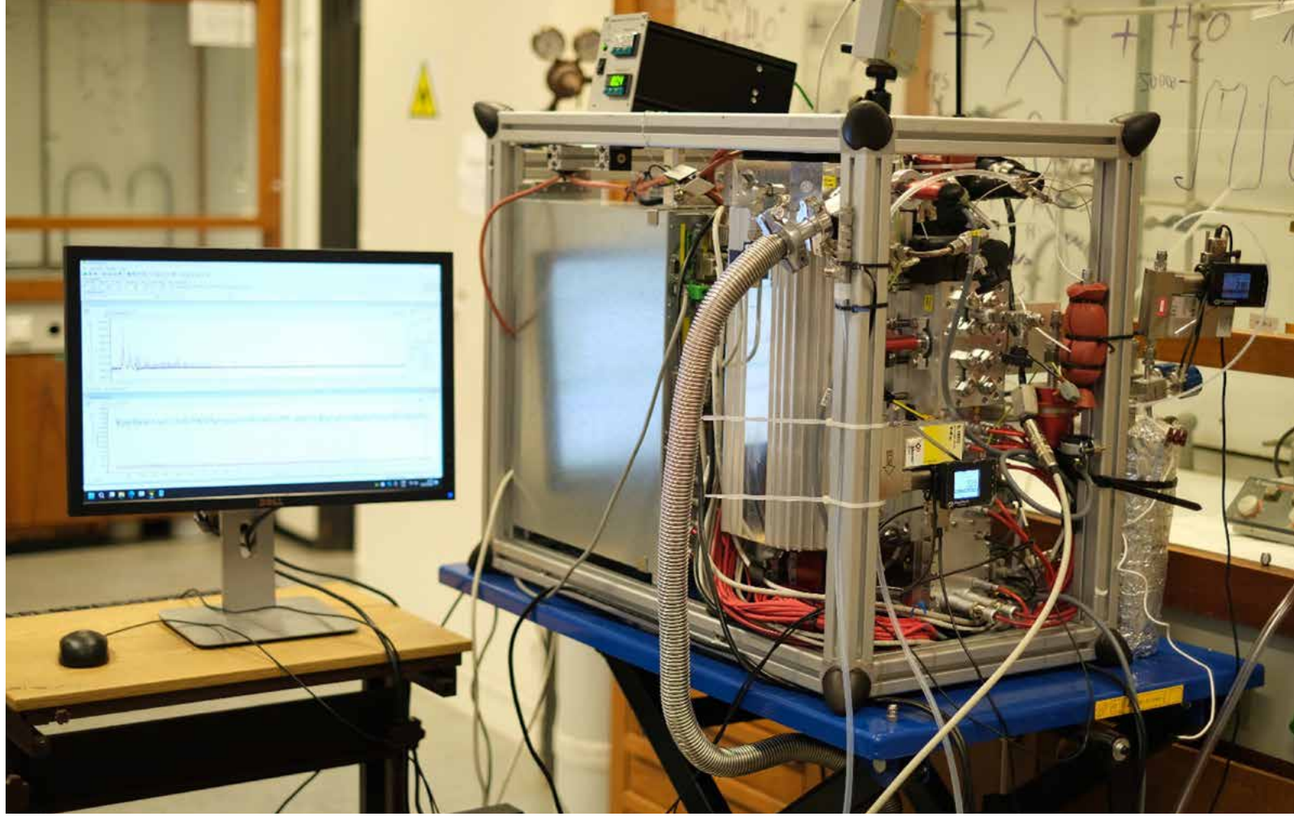

Figure 1: The PTR-MS analyzer used for the detection of atmospheric MP and NP.

Our initial work has focused on the detection of tire wear particles (TWP), *i.e.* the particles formed as a result of the wear and tear on vehicle tires, predominantly caused by their frictional contact with roadways. TWP are expected to significantly contribute to the urban atmospheric particle load, but a quantitative assessment is difficult. Our initial experimental work has focused on the development and characterization of a pyrolysis unit designed for evaporating particles collected on filters. Preliminary data indicate that the PTR-MS analyzer selectively and quantitatively detects the volatile products formed from the pyrolysis of TWP.

References

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"One of the most ubiquitous and long-lasting recent changes to the surface of our planet is the accumulation and fragmentation of plastics."

David Barnes,
British Antarctic Survey

Hot ponds in subarctic Norway are hotspots of methane emissions

François Clayer
Research scientist, NIVA

&

Jacqueline Knutson
PhD student, NIVA

Inge Althuizen
NORCE

Hanna Lee
NTNU

Tomas Mikoviny
Senior Engineer, Department of Chemistry

Heleen de Wit
Senior research scientist, NIVA/CBA

The Iškoras field site in Finnmark is a key research area in the Biogov project (NFR 2022–2027, led by UiO with NIVA and NMBU as partners) (Figure 1). Here, a thawing permafrost area surrounded by a peatland is investigated for greenhouse gas dynamics. The wetland is expected to be the ecological endpoint of the palsamire given climate warming. The decaying palsa mounts lead to formation of thermokarst ponds which will eventually be colonized by the wetland vegetation. In 2020, we started with investigations of the ponds and the wetland streams to further our understanding of the water bodies for the greenhouse gas source and sink function of this ecosystem. We collected data on water temperature and water table, water chemistry, dissolved gases and greenhouse gas emissions. Investigations on the terrestrial ecosystems were started in 2016 by Hanna Lee and Inge Althuizen, and continued until now as part of annual growing season campaigns. The terrestrial measurements include CO_2 and CH_4 fluxes along the permafrost thaw gradient including palsa mounds, thermokarst ponds, and natural succession ponds, where vegetation dominated by sedges starts to grow to cover the ponds. This work is currently in preparation as a manuscript (Althuizen, Lee et al. in prep).

In October 2021, sensors for water table and temperature were installed in three thermokarst ponds, a stream in the palsa and two stream channels in the adjacent wetland (Figure 1). The water temperature data for July to August in 2022 show that the bottom of the ponds were on average 1.5 °C warmer than the inlet channel to the wetland, e.g. 12.4 °C in the ponds and 10.9 °C in the stream (Figure 2). The sensors measure water temperature at the transition from sediment to water. Manual measurements of water temperature are taken in the free water show differences of 5oC between the ponds and the wetland stream, e.g. 11.1 °C for the stream and 16.3 °C for the ponds. Thus, these thermokarst ponds represent a much warmer environment than the surrounding wetland streams.

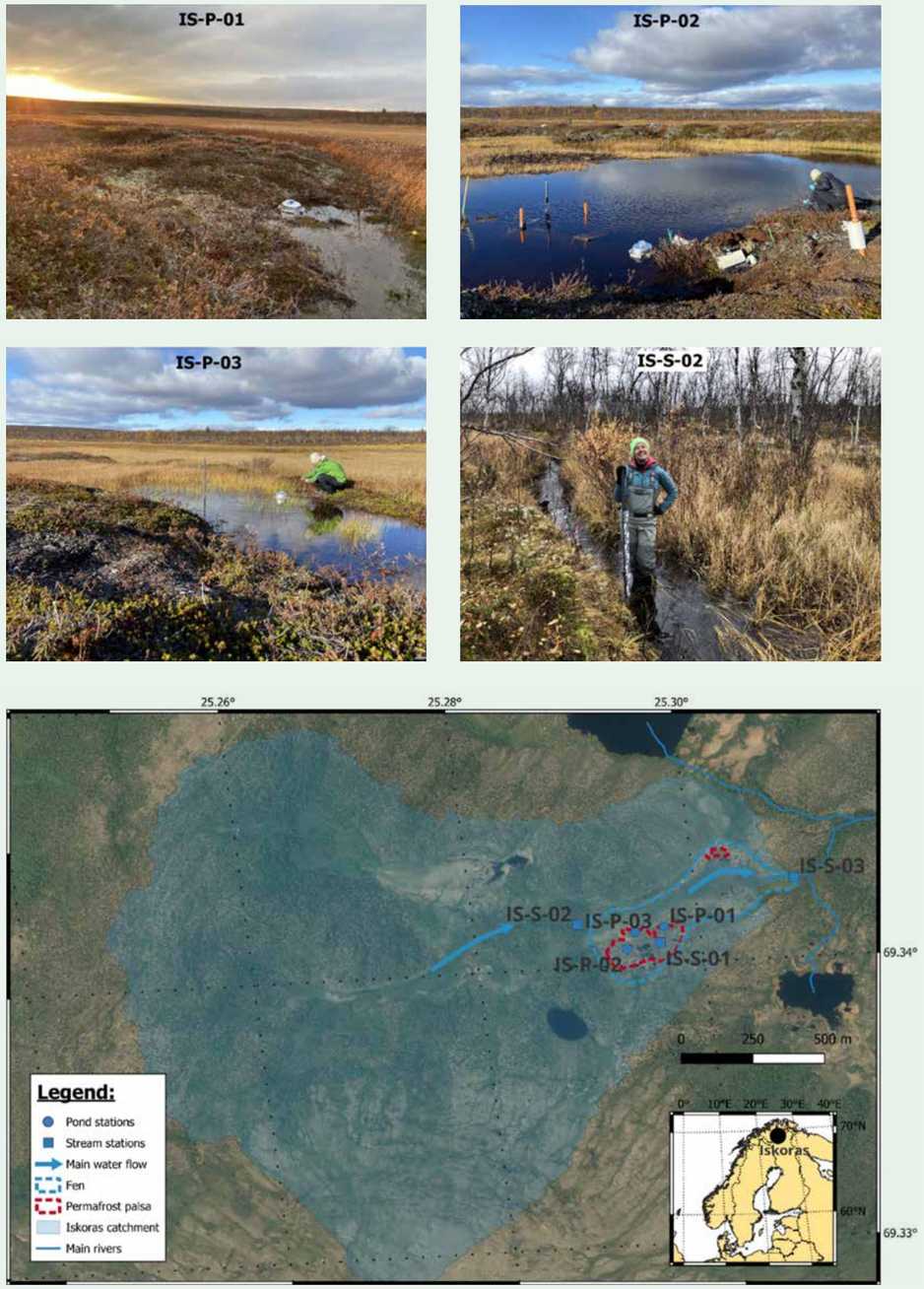
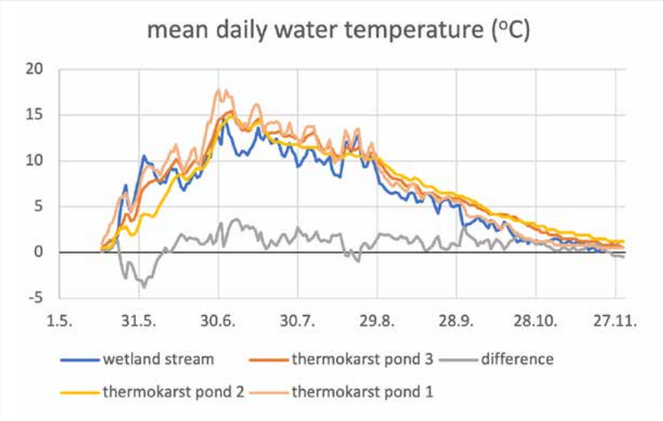


Figure 1: The Iškoras field site in Finnmark. Top four photos show ponds 1–3 and the inlet channel of the wetland (IS-S-02). The bottom aerial photo shows the location of the stations, the outline of the catchment, of the palsa and of its adjacent peatland. The blue arrows show the prevailing water flow.



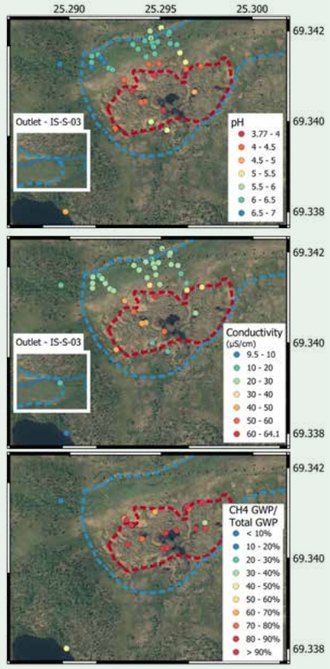


Figure 2: Mean daily water temperature in 2022, measured in-situ with trutrack sensors, in thermokarst ponds 1 to 3, and wetland stream (inlet channel IS-S-02).

Figure 3: pH (top panel) and electrical conductivity (middle panel) (measured in Autum 2022), and fraction of CH_4-GWP divided by total GWP (CO_2+CH_4) (measured in Autumn 2023) in thermokarst ponds within the palsa (dotted red line) and adjacent wetland (dotted blue line) and uphill lake (lower left).

Figure 4: Floating chamber connected to Licor (Li-7810) (left) and values measured (right).

The water chemistry data show that the ponds are very acidic (pH <4.5), rich in DOC (>25 mg C/l), and high in solutes (electrical conductivity (EC) 3.0 mS/m) compared with the wetland streams (pH>6.5, DOC <10 mg C/l, EC 2.0 mS/m). Also, the dissolved gas data indicate high concentrations of dissolved CO_2 and CH_4 in the ponds compared with the wetland streams (Knutson et al., in prep). In the autumns of 2022 and 2023, campaigns for key water chemical components and greenhouse gas emissions were done to investigate lateral changes in the transition from palsa to wetland. The changes in pH and electrical conductivity demonstrate clearly that solutes are transported from the palsa into the wetland, with a declining effect as one moves further away from the palsa (Figure 3).

The greenhouse gas emissions were measured using a combination of a floating chamber and Licor equipment (Figure 4). The Li-7810 is a portable CO_2/CH_4/H_2O gas analyzer (made available from Inge Althuizen, NORCE) which was used to follow the build-up of CO_2 and CH_4 under the floating chamber. Among the many metrics used for comparison of the relative influence of the greenhouse gas emissions on climate, we use a comparison based on simple CO_2-equivalents (where CO_2 and CH_4 are weighted equally), and Greenhouse Warming Potential (GWP). When expressed in GWP, CH_4 is weighted higher than CO_2 because of its higher radiative efficiency, but this weighing factor declines over time given its shorter atmospheric lifespan (Arsenault et al. 2022).

Expressed in CO_2-equivalents, CH_4 emissions were on average ca 5% of the total CO_2 + CH_4 evasion from the thermokarst ponds, suggesting a minor role of CH_4 in the carbon balance. However, the contribution of CH_4 to GWP (for a 20-year period) for combined CH_4 and CO_2 evasion was usually between 70 and 99%, and in several measurement points the contribution of CH_4 was over 80% (Figure 3). In the wetland stream CH_4 emissions are minimal compared with CO_2 while for lake located at higher elevation than the palsa, the GWP of each gas was similar – though the fluxes themselves were among the lowest found at the points measured in the landscape.

We conclude that the thermokarst ponds are the warmest water bodies of this palsa to wetland continuum in the summer (July–September), and that palsa water bodies are hotspots of CH_4 emissions compared with the wetland, presenting an important positive feedback to climate warming. The results will be published in a manuscript (Knutson et al. in prep). To further understand the greenhouse gas source and sink function of the palsa to wetland continuum, lateral fluxes of organic matter will be quantified and the fate of the dissolved organic matter will be studied. Repeated campaigns with the Li-7810 would be beneficial for quantification of greenhouse gases from this aquatic continuum.

References

Althuizen, IHJ., Christiansen, CT., Michelsen, A., Dörsch, P., Pirk, N., Risk, D., Westermann, S., Lee, H. In preparation. Long lasting greenhouse gas emissions beyond abrupt permafrost thaw event in permafrost peatlands

Arsenault J, Talbot J, Brown LE, Holden J, Martinez-Cruz K, Sepulveda-Jauregui A, Swindles GT, Wauthy M, Lapierre JF (2022) Biogeochemical Distinctiveness of Peatland Ponds, Thermokarst Waterbodies, and Lakes. Geophys. Res. Lett. 49(11): 13

Knutson, J., F. Clayer, P. Dörsch, S. Westermann et al., in prep. Water chemistry and dissolved gas concentrations in water bodies in degrading thermokarst compared with surrounding wetland streams, in Iškoras, northern Norway

Thicker snow and increased runoff combine to trigger permafrost collapse on Svalbard

Frans-Jan Parmentier
Senior researcher, Department of Geosciences
&

Sebastian Westermann
Professor, Department of Geosciences

Recent research from the CBA has shown that increased snow cover can lead to the abrupt thaw of permafrost – perennially frozen ground – causing a release of greenhouse gases to the atmosphere. While snow cover is steadily disappearing as a result of climate change, this decline is not happening uniformly and everywhere. Across the Arctic, precipitation is increasing due to climate change, and in areas that remain below freezing, this means that we can still expect an increase in snow depth following more snowfall in winter. Snow acts akin to a blanket, insulating the ground from the coldest winter temperatures. Thicker snow, therefore, warms the soil and accelerates the thaw of permafrost – potentially contributing to carbon release from these frozen soils.

While it is certain that snow cover will change in a future, warmer Arctic, much remains unknown of how the interactions among snow and permafrost will alter surface hydrology, and how this may amplify soil carbon loss. Permafrost landscapes are highly diverse, containing many ice-rich features, with exotic names such as palsas or pingos. Another common ice-rich landscape feature are ice wedges. As the name implies, these are narrow cracks in the ground filled with ice, which form when water enters these frost cracks in spring and then refreezes. After centuries or millennia of thawing and refreezing, ice wedges develop the polygonal patterns typical of arctic landscapes (Figure 1). While ice wedges take a long time to form, they are particularly vulnerable to thaw because they hold a large amount of ice. When this ice melts, the surface sinks down, and soil carbon may be lost in the process.

This transformation of the landscape can happen rather quickly, as we show from the unforeseen side effects of a field experiment on the High-Arctic archipelago of Svalbard. Together with researchers from the Arctic University of Norway in Tromsø, we studied how the collapse of several ice wedges was triggered by increased snow depth from a snow fence experiment. Snow fences are practical tools to passively increase snow cover thickness, by decreased windspeed on their leeward side, and to study subsequent impacts on ecosystems and soils. This snow fence experiment was initiated to study snow-vegetation interactions, and not systematically monitored for indications of abrupt permafrost thaw. However, within a decade of artificially raised snow depth, the top of the ice wedge troughs deepened, and at one of the fences a large pond had formed.

While a similar response has been seen at other snow fence experiments, there was an unexpected change downstream in the landscape. At a distance of 25–75 meters, several ice wedges had collapsed, forming a 50 m long and 1.5 m deep thermo-erosion gully in the landscape (Figure 2). This happened

Figure 1: Low-centered ice wedge polygons in the Indigirka delta near the town of Chokurdakh, Northeast Siberia. Photo: Frans-Jan Parmentier

“Snow is not just a protective layer – it can also accelerate permafrost thaw, triggering rapid landscape changes and releasing long-stored carbon into the atmosphere.”

as follows: when the troughs on top of the ice wedges deepened, surface run-off was concentrated through them, increasing mechanical erosion, and causing more subsidence. In short: deeper ice wedge troughs collect more snow, which leads to more warming and again subsidence. The gully formed not just from the warming effect of the snow, but also from an increase in the flow of water through the ice wedge network.

From the size of the gully and soil carbon samples taken nearby, we estimate that 1.1 to 3.3 tons of carbon were removed from this location, transported towards the fjord through a nearby stream. To identify what happened to this carbon, we took water samples from the thermo-erosion gully, and analyzed these for dissolved and particulate organic carbon (DOC and POC), their stable isotopes δ13C, and particulate nitrogen (PN). These analyses showed that DOC levels in the gully were lower than those of nearby natural thaw ponds, while there was a strong inverse relationship of POC:DOC with oxygen. Isotopic values also point towards the eroded soil as the source of carbon. This suggests that a portion of the mobilized carbon could have entered the atmosphere as CO_2.

Abrupt thaw processes like the ones we show here have the potential to significantly increase permafrost carbon loss on top of what is projected from gradual thaw, but it remains uncertain how sensitive these thermokarst processes are to future changes in snow cover and surface runoff. Most land surface models only simulate gradual thaw, not subsidence, while hillslope processes are just starting to be implemented. Current projections of the strength of the permafrost carbon feedback may therefore be severely underestimated. Our research shows the importance of studying the interactions among snow, runoff, and permafrost thaw to better understand how this may affect the release of greenhouse gases to the atmosphere.

Figure 2: Large downstream effects of increased snow cover from a snow fence experiment on Svalbard. The fence is in the background, the collapsed ice wedge is shown in the foreground – forming a deep thermo-erosion gully. Photo: Frans-Jan Parmentier.

MIMICS+: A new microbial model for decomposition of organic matter in soil

Terje Berntsen
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&

Elin Aas
iPhD student, Department of Geosciences

The terrestrial ecosystems stores more carbon than the total amounts of carbon (as CO_2) in the atmosphere. With a changing climate and increasing CO_2 levels in the atmosphere, there is a possibility for significant climate-carbon feedbacks in the system. Global climate models thus need to represent both the living vegetation (i.e. the primary production) and the biogeochemistry of soils (including wetland and permafrost) to be able to quantify the feedbacks. At CBA, PhD-student Elin Aas has improved and adapted a microbial model (MIMICS, Wieder et al.) for boreal soils. The intention with the model is that it will be the soil decomposition module in the Norwegian Earth System model (NorESM). Thus, the challenge has been to keep it simple enough to be used on a complex global model, and still detailed enough to represent the important processes quantitatively with acceptable accuracy. The model is accepted for publication in Geoscientific Model Development (Aas et al., 2024a).

The model structure is shown in Figure 1. It includes prognostic equations for biomass of saprotrophic microbes (bacteria and fungi) as well as mychorrizal fungi. Input of carbon is different litter types from vegetation and carbon allocated from plants to mychorrizal fungi for active uptake of nutrients (in the model nitrogen). There is heterotrophic respiration of CO_2 from the microbes, depending on their carbon use efficiency (CUE). The CUE is calculated in the model by the C:N ratios needed to build microbial biomass, and the available nitrogen from litter and inorganic nitrogen in the soil. Under nutrient poor conditions, common for the boreal biome, the CUE will thus tend to be reduced.

The model has been tested using observations of carbon and nitrogen content in soil profiles from Norway. In the comparison 50 sites from podzolic soils have been used. Figure 2 shows the total soil organic carbon for the full data set (approx. 500 sites) and comparison between observations and model simulations for a subset of 50 sites. For comparison, the original Community Land Model (CLM5) as used in NorESM (using the Century decomposition model) is shown for the same 50 sites. Bothe the new MIMICS+ model and the Century model is driven by the same temperature and moisture content in the soil and equal litter and nitrogen input.

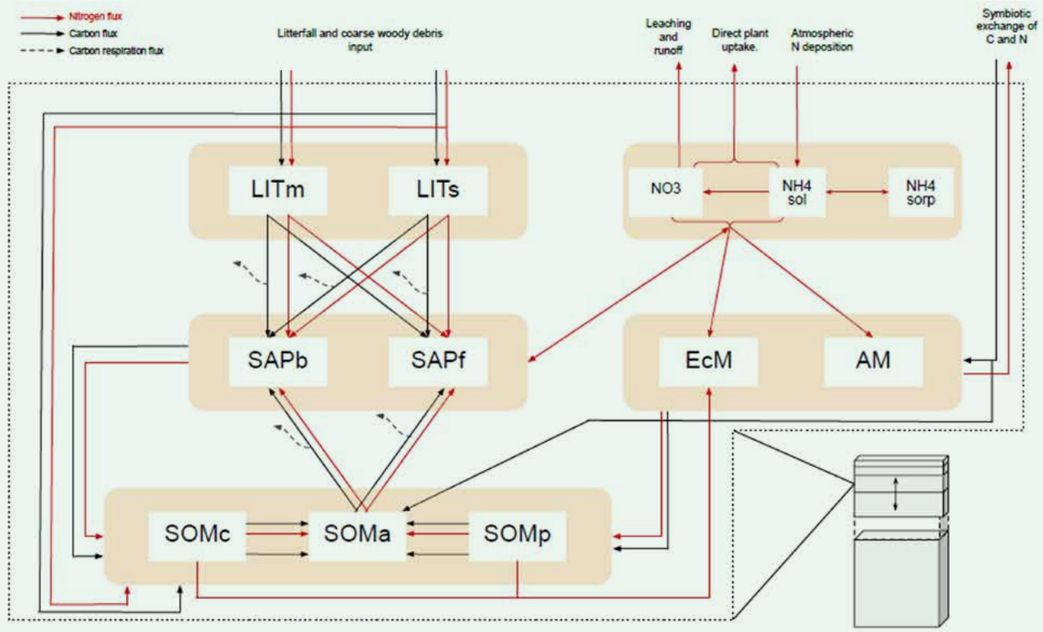

Figure 1: Schematic showing C and N flows within each layer of the model. Black arrows indicate carbon fluxes ($gCm^{-3}h^{-1}$) while red arrows indicate nitrogen fluxes ($gNm^{-3}h^{-1}$). The dashed black arrows symbolize C leaving the system as heterotrophic respiration. LITm, LITs: metabolic and structural litter. SAPb, SAPf: saprotrophic bacteria and fungi. EcM, AM: ecto- and arbuscular mycorrhizal fungi. SOMc, SOMa, SOMp: chemically protected, available and physically protected soil organic matter. NO_3, NH_4sol, NH_4sorb: Inorganic N in the form of NO_3, NH_4 in solution and NH4 sorbed to particles, respectively.

Decomposition of organic matter in soil have been measured experimentally through litterbag experiments. The model (MIMICS+) has been used to simulate an extensive experiment from Canadian boreal cites, where 11 different litter types from native species were buried and sampled over a period of 6 years. All 11 litter types were buried at 9 different locations across Canada. In the model simulations, the litter types were represented based on the composition (structural versus metabolic litter) and their C:N ratio. The 9 different sites were simulated based on climate forcing data (soil temperature and moisture) generated by simulations with the CLM model forced with atmospheric reanalysis data. Figure 3 shows comparison of the fraction of remaining litter mass (in %) between the model

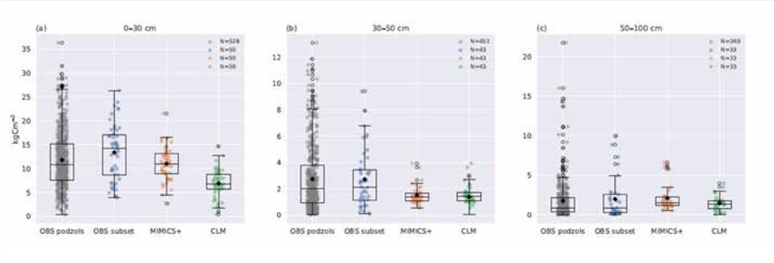

Figure 2: Modeled and observed C stocks in (a) 0–30 cm, (b) 30–50 cm, (c) 50–100 cm soil depths for; all observed podzols except the 50 modeled ones (left), the 50 modeled sites (center-left) from Strand et al. (2016), simulated with MIMICS+ (center-right) and with CLM (right). From Aas et al. (2024a)

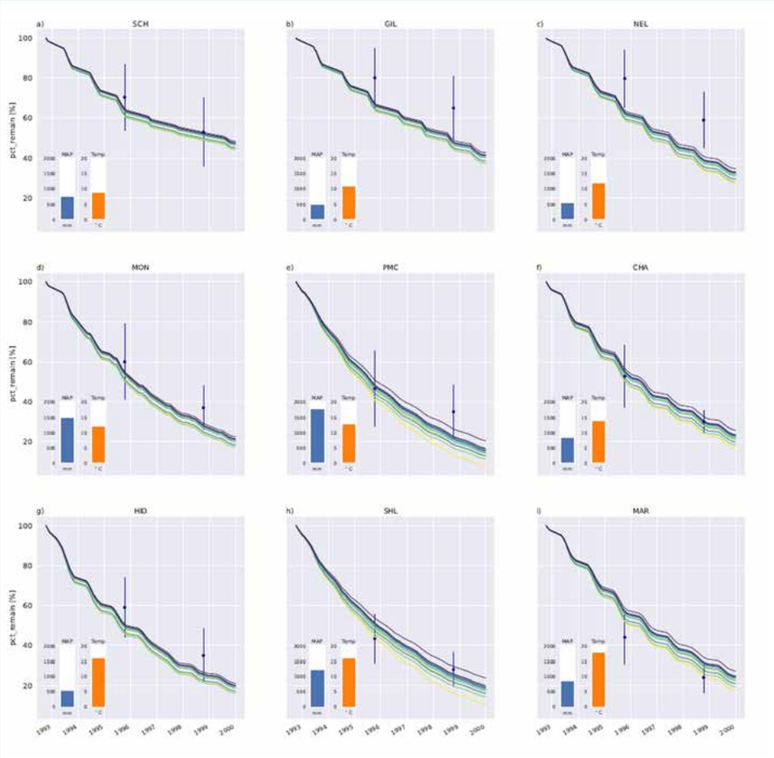

Figure 3: Percent remaining mass in litterbags at CIDET sites. The lines show model simulations, with the color indicating the type of litter. The lighter the line color, the lower the C:N ratio. The dots show observed mean mass loss of each site across all litter types (Trofymow et al., 2002) with the error bar showing the standard deviation (SD). The SD was calculated from the reported standard error of the mean with N = 11. The inserted bars show the 1951–1980 average MAP (blue) and Jun–September average temperatures (orange) for each site. From Aas et al. (2024b)

“MIMICS+ bridges the gap between microbial ecology and global climate modeling, helping us refine predictions of soil carbon dynamics in a changing world.”

and the experimental data (after 3 and 6 years). In general, the model seems to do an excellent job in representing the decomposition rates, with higher rates at warmer and wetter sites.

So far, the simulations do not include a two-way coupling between the soil and the vegetation. Since both microbial growth and vegetation growth depend on nutrient availability, the system should include this two-way coupling in order to represent possible feedbacks in the system properly. Within the Biogov project at CBA, work is now underway by PhD-student Betty Wörner to include the MIMICS+ module properly in the CLM model.

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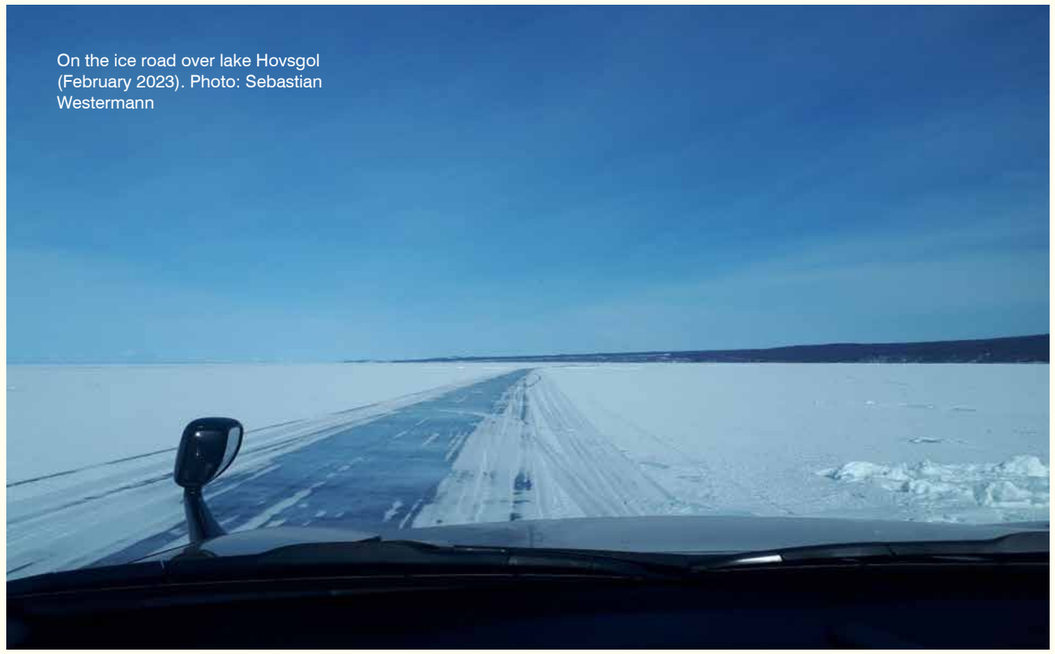
Wieder et al., Representing life in the Earth system with soil microbial functional traits in the MIMICS model, Geosci. Model Dev., 8, 1789–1808, 2015 *https://doi.org/10.5194/gmd-8-1789-2015*

Mongolian field work photo essay: Permafrost4life

In the “Permafrost4Life” project funded by the Research Council of Norway, we investigate the interplay between permafrost and ecosystems in Mongolia and how this is affected by climate and land use change. Our research focus is the impact of intense livestock grazing on ground temperatures, as well as disturbances of forest ecosystems by insect outbreaks, fires and logging. During the project CBA researchers have visited Mongolia multiple times and conducted field work with colleagues from our Permafrost4Life partner the Mongolian Academy of Sciences. During a field campaign in late winter, we investigated the effect of snow trampling by grazing animals, which can lead to a net cooling of the ground. In summer, we focussed on the canopy structure of natural forests and compared them to disturbed forests. For this purpose, we got assistance from DroneLab@UiO to survey large areas efficiently using a drone-borne laser scanner. Our field efforts are aimed at setting up and improving current numerical models, which will allow us to simulate the permafrost conditions for different climate and land use scenarios.



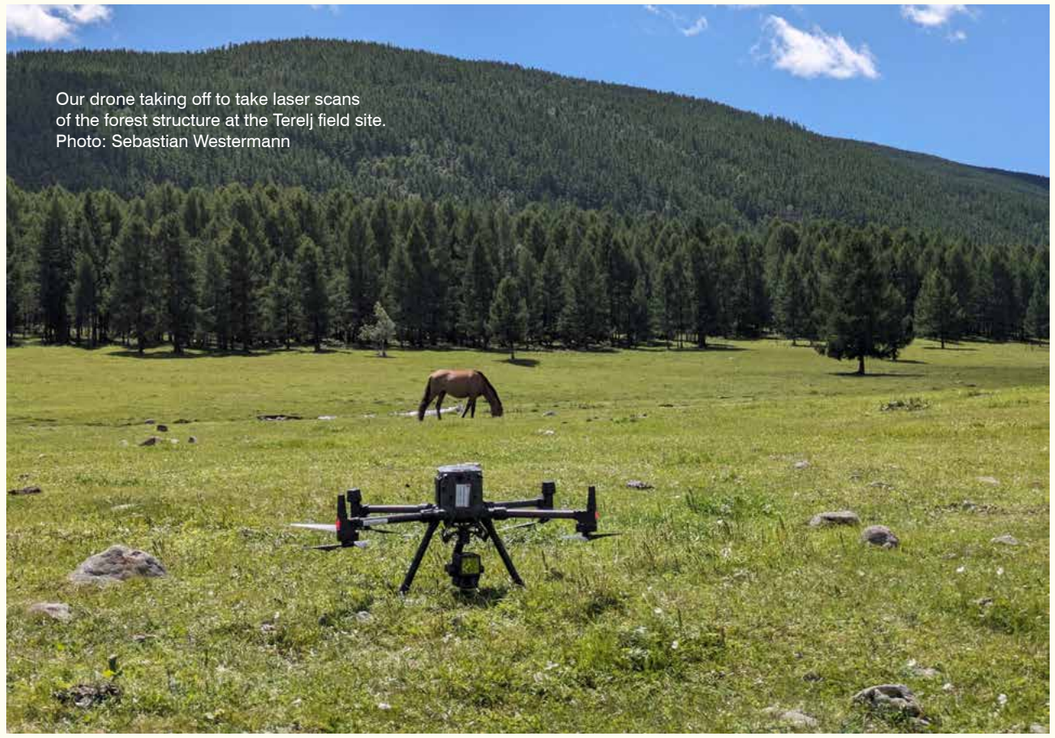
On the ice road over lake Hovsgol (February 2023). Photo: Sebastian Westermann

Livestock numbers in Mongolia – all these animals feed in natural ecosystems. Photo: Sebastian Westermann

Breakfast sheep. Photo: Sebastian Westermann

Mongolian landscape close
to the capital Ulaanbaatar.
Photo: Sebastian Westermann

Reviewing the drone data in camp.
Photo: Sebastian Westermann



Our drone taking off to take laser scans
of the forest structure at the Terelj field site.
Photo: Sebastian Westermann

A forest killed by an insect outbreak.
Photo: Sebastian Westermann

Finnmark field work photo essay

Sampling of the active layer of the palsa permafrost site Aidejavri, Finnmark. Photo: Clarissa Willems

Sampling of the fresh peat around the palsa permafrost site Iskoras, Finnmark Photo: Clarissa Willems

Sampling of the active layer of the palsa permafrost site Iskoras, Finnmark. Photo: Clarissa Willems

Sampling of permafrost at Iskoras, Finnmark. Photo: Clarissa Willems

How do dwarf shrubs contribute to carbon capture?

Figure 1: A dwarf shrub plant collection site at Senja, July 2023. Photo: Ane Vollsnes, UiO

Ane V. Vollsnes
Researcher, Department of Biosciences

Dwarf shrubs are widespread in boreal and sub-arctic vegetation, living from sea-level to alpine areas and at all latitudes in Norway. They thrive in open areas as well as on the forest floor (Figure 1). Despite the widespread distribution of dwarf shrubs, they are not well studied in the context of carbon capture and carbon storage or in the context of biological soil processes and mycorrhiza. For climate research and modelling of the vegetation – climate interaction we need good knowledge of the most common plant functional types in our areas. In the DURIN project (The underappreciated roles of dwarf shrubs in responding to and influencing global climate change) we aim at contributing with more knowledge of dwarf shrubs. We have established four main study areas, including coastal and more inland areas at 60 °N (Lygra and Kaupanger) and at 69 °N (Senja and Kautokeino). In addition, we have one site in forest and one in open heath in all four areas. This collection of sites gives us the opportunity to study the variance of the dwarf shrub traits and interactions with microclimatic and soil microbiological conditions across great climatic gradients.

Photosynthesis with carbon capture is one of the most important impacts of vegetation on the global climate. The growing season restricts the annual carbon capture, and therefore the transfer from winter dormancy to summer activity in spring needs to be well described for boreal and sub-arctic vegetation modelling.

Three of the most common dwarf shrubs are heather (Calluna vulgaris), crowberry (Empetrum nigrum) and lingonberry (Vaccinium vitis-idaea). They are all evergreen, meaning that they keep green leaves through winter. This may give them a head start in capturing carbon and nutrients in spring. At the same time, they may contribute to a fresh addition of carbohydrates to the soil community of microorganisms. The overwintering leaves need to change from a winter physiological mode, where they protect themselves from frost and light, to summer mode, where they don't need frost tolerance and where they exploit the energy of the light for driving photosynthesis. Next they will start producing new leaves, further increasing their capacity to capture carbon. European blueberry (Vaccinium myrtillus) is the fourth dwarf shrub of our project. In spring, these plants have no leaves from the previous seasons but produce new leaves from buds. Therefore, they can be expected to be somewhat later at contributing with carbon capture.

Between the sites we are studying, we have a large contrast of snow cover duration, from practically no snow at the coast to snow melt occurring in May, or even June, in Kautokeino. This has substantial effects on the start of the growing season, which is often defined as the time of bud break. The time available for producing all the flowers, leaves and stems before peak season and fruits and seeds before the end of the season is therefore shortened by a long lasting snow cover. There is obviously some phenotypic plasticity in these widespread dwarf shrub species, but from field observations we cannot know whether this relies on adaptation (genetic component), acclimation to the microclimatic conditions (environmental component) or the interaction between these. We have collected plants from all the sites and are growing them in a common environment (Figure 2) to be able to better describe the genetic component. If there has been different adaptation within a species between plants of contrasting origin, we may observe different timing of the physiological acclimation to warmer temperatures and more light or perhaps different timing of bud break and flowering. As soon as the plants are transferred from winter conditions to spring and summer conditions, we will start a set of measurement campaigns to capture the transition from winter physiological mode to summer physiological mode in the evergreen plants. We will measure photosynthesis and we will count and measure repeatedly the new leaves and flowers produced to capture the dynamics of each plant.

As the plants get into summer, we will also perform other experiments with them, to get more details about their physiological responses to specific light and drought conditions.

Figure 2: The plants are kept under winter conditions for a period in the C3 climate lab of the Department of Geosciences before they are transferred to a growth chamber with spring and summer conditions again. Photo: Ane Vollsnes

Photo: Getty Images

Outreach

CBAs researchers love to engage in public outreach. They participate in public debates, create newspaper articles and write books, and look forward to doing this even more in the years to come.

Outreach 2023

Chronicles and popular science

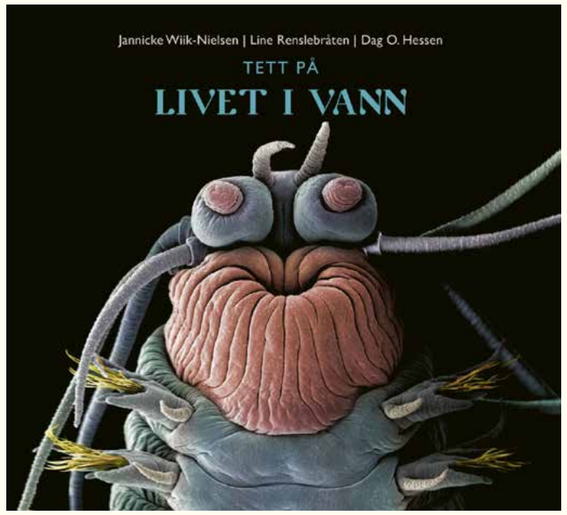
Chronicles and interviews

- Vellykket klimaaktivisme handler ikke om seg selv.
  Parmentier, Frans-Jan W. Klassekampen January 2.
- Forskere: Stadig ny bygging av hytter og veier passer ikke med målene om å bevare norsk natur
  Kjørstad, E., Vandvik, V., Hessen, D. O., interview, forskning.no, January 16.
- Lågendeltaet er ikke lenger vernet. Hva blir det neste?
  Parmentier, F.-J. W., Klassekampen, February 20.
- Hvorfor mangler naturkartlegging tillit?
  Halvorsen, R. & Bryn, A., Altinget, March 1.
- Når isbreene smelter, renner også klimahistorien ut i havet
  Parmentier, F.-J. W., Klassekampen, May 22.
- Hva skjer med plantene i Norge?
  Bjorå, C. S., Elven, R., Hessen, D. O., NRK P2 EKKO, June 1.
- Et varmt mysterium i verdens-havene
  Parmentier, F.-J. W., Klassekampen, July 3.
- Linking forest to fish: a story of coastal darkening
  Hessen, D. O., Opdal, A. F., SILnews, July.
- Mens isen smelter, gir regjeringen bånn gass
  Parmentier, Frans-Jan W. Klassekampen, August 14
- Hvordan skal vi møte den neste «Hans»?
  Parmentier, F.-J. W., Klassekampen, September 18.
- Regjeringens grønne bok er full av eventyr
  Parmentier, Frans-Jan W. Klassekampen, October 16
- Vi ser ikke skogen for bare trær
  Parmentier, F.-J. W., Klassekampen, November 20.

Selected talks and presentations

- Bird impacts on biological communities in Arctic ponds – preliminary results, SEES.nl Science Day, Groningen, arranged by Arctic Centre, University of Groningen
  T. C. Jensen, A. K. Schartau, M. Majaneva, D. O. Hessen, A, Eiler, M. J. J. E. Loonen, B. Skjelbred, February 4
- Natur i endring – hva skjer med den norske naturen? Invited oral seminar presentation at Naturtreff, arranged by Sparebankstiftelsen DNB, Sentralen i Oslo
  A. Bryn, May 24

Book



Tett på livet i vann

Fontini forlag. Wiik-Nielsen, J., Renslebråten, L., **Hessen, D. O.**, 2023. ISBN: 978-82-8373-185-9

> In 2023, CBA members contributed to science communication with *Tett på livet i vann* (*Close to Life in Water*), an educational and visually book for curious young readers. It unveils the hidden world of aquatic life through microscopic images magnified up to 15,000 times alongside fascinating facts about Norway's marine ecosystems. The book combines award-winning microscopy photography with engaging storytelling and supports CBA's mission to inspire young minds and promote environmental awareness.

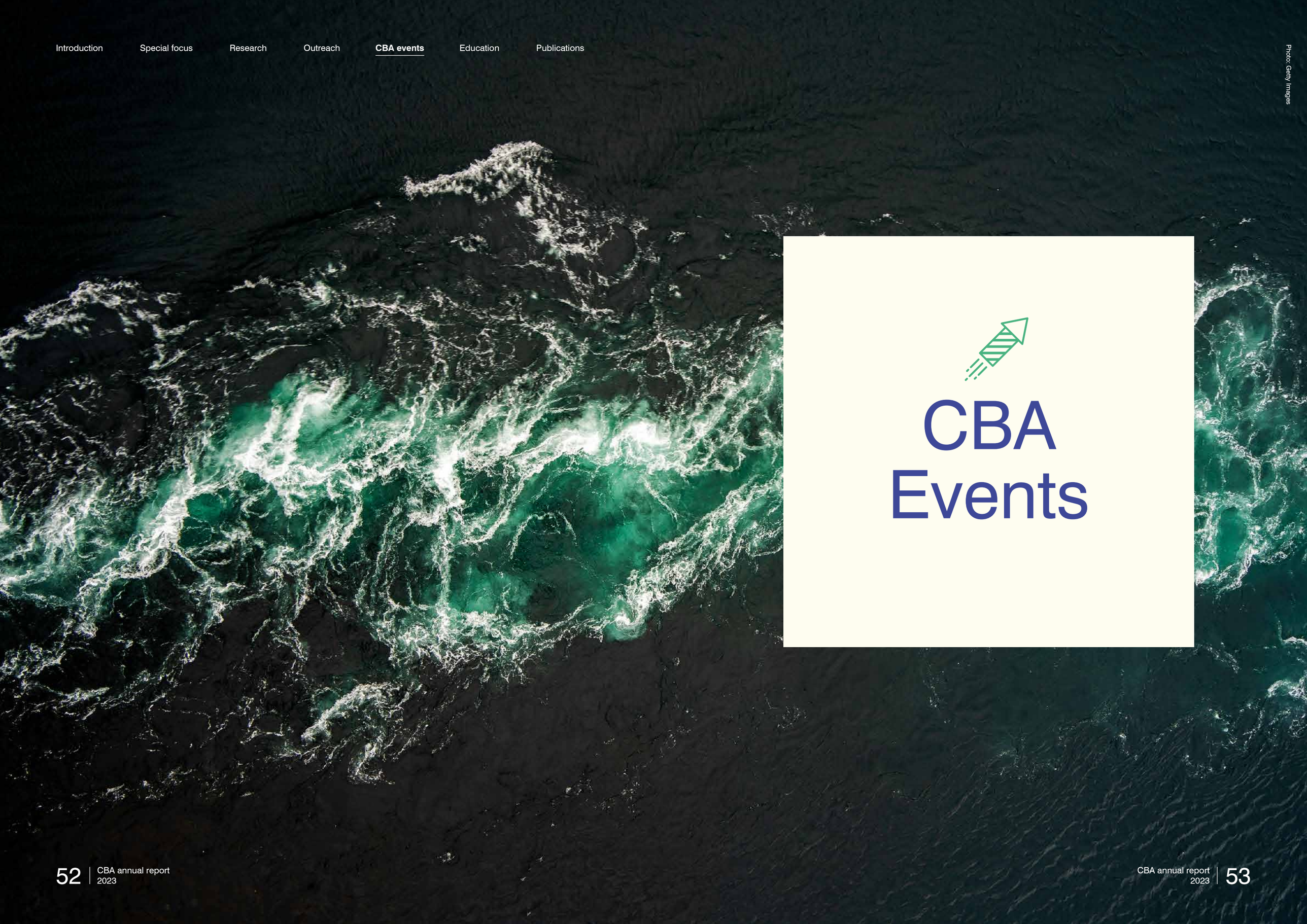


Photo: Getty Images

CBA Events

CBA events

GeoWednesday

Realfagsbiblioteket, Vilhelm Bjeknes' hus

20 September 2023

Professor Terje Koren Berntsen, UiO

Title: *Klimafølsomheten: Det store spørsmålet i klimaforskningen*

EMERALD Open Science Day

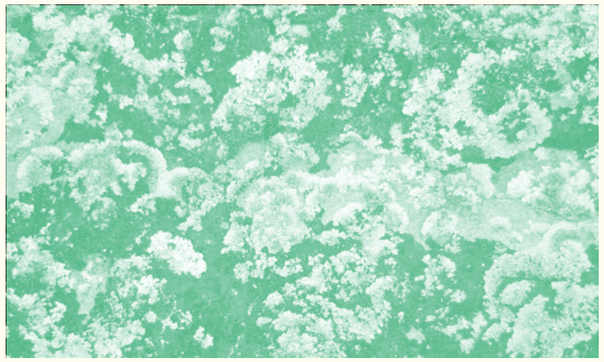
Klimahuset, Tøyen

17 October 2023

The EMERALD Open Science Day was the closing meeting of the project with the aim to share the experience and knowledge gained throughout the project period between 2019 and 2023.

On October 17, 2023, the EMERALD Open Science Day took place at Klimahuset, Tøyen, marking the culmination of the EMERALD project (2019–2023). This public event was free and open to all, inviting climate scientists, students, and the public to engage with the latest research on ecosystem-climate interactions in high-latitude environments.

Internal CBA events



PhD defense

September

Eva Lieungh – Changing alpine vegetation dynamics: insight from complementary modelling and observation approaches

November

Camille Crapart – Origin and Fate of Dissolved Organic Matter under the Environmental Changes of the 21st Century

November

Juditha Aga – The thermal regime and stability of permafrost in sloping terrain – observations and numerical modelling

Tuesday talks 2023

CBA internal seminar 2023

28 March

Sebastian Westermann and Manon Bajard – Introducing CBA leader Sebastian Westermann and new centre coordinator Manon Bajard

23 May

Eira Carlsen and Elisabeth Wörner – Track hunt: Following the footsteps of carbon – into the future

30 May

Dag O. Hessen – Taking nature into account: Do we grossly underestimate the Norwegian GHG emissions?

15 September

Franck Lejzerowicz – From human guts to the deep-sea benthos, prokaryotic or eukaryotic: a microbiome travel

Joint presentation with AQUA/CEES seminar

31 October

Joel White, University of Gothenburg – Not all peatlands are created equal: Three sub-arctic peatlands under rapid permafrost degradation

28 November

Mats Rouven Ippach – Finnmark 2023: Or, There and Back Again

CBA Early Career Researcher meeting

The inaugural self-organized young researcher meeting was held in Drøbak October 11, 2023

- **Maria Hammerstrøm** – Presentation and Poster skills
- **Ilan Villanger** – Life as a young researcher

CBA annual meeting 2023

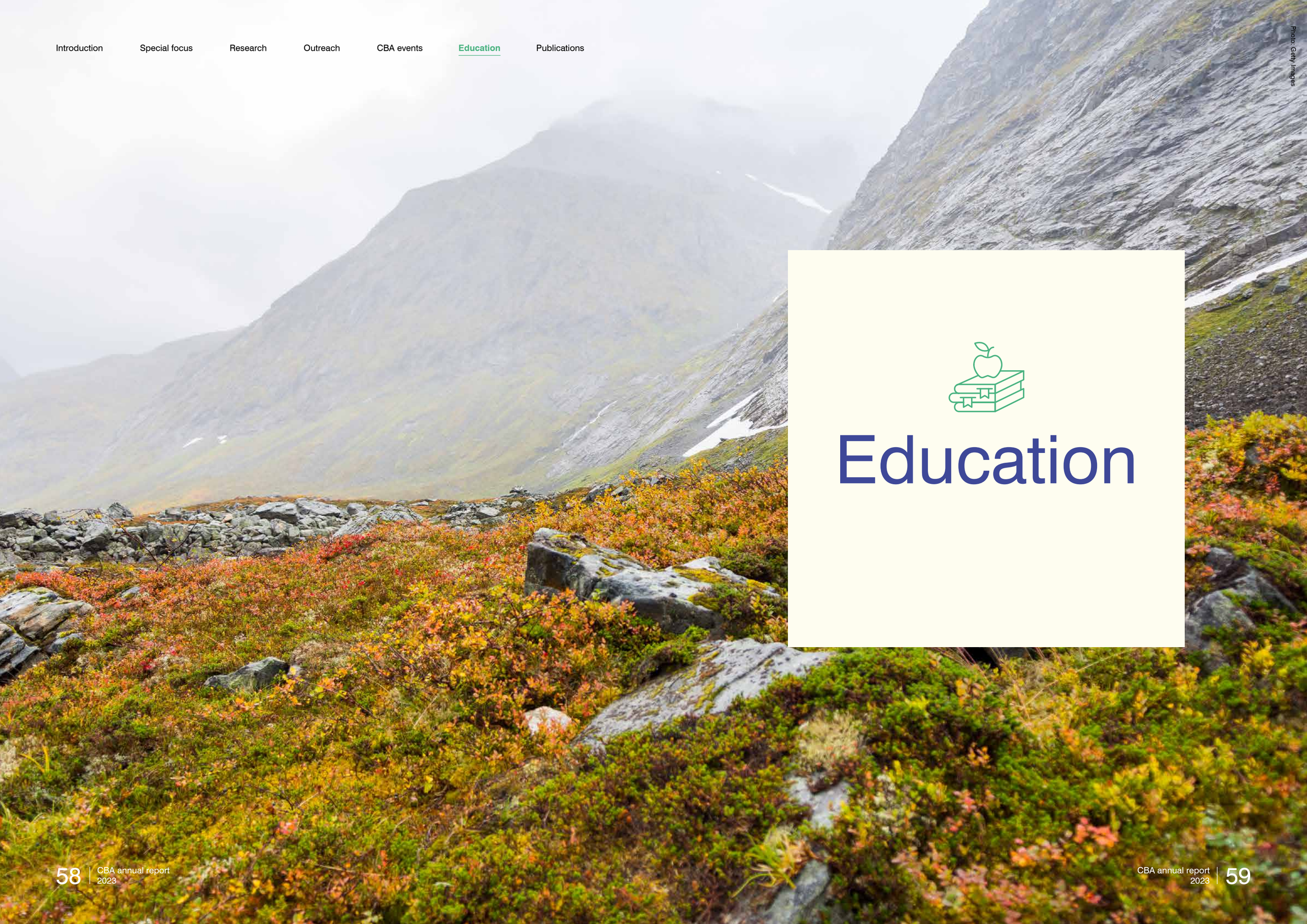
The CBA annual meeting was held in Ås and Drøbak October 12–13, 2023

Thursday 12th October

- **Sigrid Trier Kjær** – Soil and GHG research at NMBU field station Kjerringjordet
- **Thomas Rohrlack** – Nitrogen limitation may promote bloom formation and expansion of the nuisance alga G. semen
- Overview of lab facilities at NMBU-MINA and demonstration of field trials
- **Dag Hessen** – BioGov and the boreal carbon budget
- **Heleen de Wit** – Water chemistry and dissolved gas concentrations in water bodies in degrading thermokarst compared with surrounding wetland streams, in Iškoras, northern Norway
- **Terje Koren Berntsen** – A new microbial soil decomposition model for use in Earth System Models. Principles, first results and future plans.
- Poster session: **Eira Carlsen, Elisabeth-Christina Wörner**

Friday 13th October

- **Franck Lejzerowicz** – A metagenomic data processing pipeline: development for CBA needs?
- **Sebastian Westermann** – The carbon cycle in permafrost environments – challenges and perspectives
- **Norbert Pirk** – Update on eddy covariance measurements in Iskoras
- **Armin Wisthaler** – Atmospheric micro- and nanoplastics – A short introduction
- **Aleksandr Berezovski** – How terrestrially derived dissolved organic matter affects coastal environments
- **Rolf Vogt** – Unexpected increases in calcium concentrations – Are we in a post acid rain era?
- **Frans-Jan Parmentier** – Contrasting trends in snow thickness govern future trajectories of Arctic-boreal carbon release
- **Christina Nadeau** – Missing the (Tipping) Point: The Role of Climate Tipping Points on Public Risk Perceptions in Norway



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Education

Education

Courses at CBA

CBA's researchers teach several courses on topics related to biogeochemistry.

KJM1700

Environmental and climate challenges

The course provides a basic scientific introduction to the environmental challenges and several of the UN's sustainability goals, and how environmental authorities use scientific insights. A group project assignment provides an in-depth look at a chosen environmental theme and training in scientific publishing. The course has an interdisciplinary approach that makes it suitable for students from other disciplines who need basic knowledge of the environment and climate in the academic community.

BIOS3070/KJM3070

Biogeochemistry

The global environment is tightly linked to the global cycles of carbon and other key elements like nitrogen, phosphorus and iron. These elements are also closely related to the hydrological cycle as well as biological production, diversity and ecosystem services, and chemical properties of the environment. The course will focus on couplings between biological, geological and chemical processes, on the interactions between climate and the environment, and human impacts on these processes.

The lectures are common for the courses KJM3070 and KJM4070 while most of the colloquia, workshops and labs are being held separately.

TFF3219

Cross-disciplinary ecology in the Anthropocene

Anthropocene, the age of humans, is suggested as the name for the geological epoch that we are currently in. Humans are seen as the most important force in the large changes that can be observed in climatic patterns, atmosphere, biodiversity, cryosphere, seas and lakes. IPCC has stated that the climate change is caused by anthropogenic activity, indicating a new link between humans and nature.

This implies a cross-disciplinary challenge for any scientific discipline, from humanities and social sciences to biology, geology and other natural sciences. With the cross-disciplinary research project ECODISTURB as our starting point, this course provides an opportunity to understand and discuss the cross-disciplinary challenges arising in the Anthropocene.

GEO4161

Contaminants in the geoenvironment

Contaminants in soils and ground water pose a threat to our society and the limited land and water resources. The course will cover:

- Types of contaminants, both organic and inorganic
- Physical/chemical distribution among phases/media
- Biogeochemical processes in soils and groundwater
- Transport of contaminants
- Risk assessment
- Natural attenuation

BIOS4500

General Toxicology

The course will cover basic toxicology and ecotoxicology, including how toxic substances are taken up in the organisms, distributed, biotransformed and excreted, how toxic substances react with biomolecules and downstream consequenses for the organism, as well as knowledge about toxic substances, e.g. metals, organic contaminants and pesticides. The course aims to provide a holistic view of the topic by bridging human toxicology and ecotoxicology.

GEO4904

Atmospheric Chemistry

The course deals with the basic processes that govern the composition of chemically active species in the atmosphere (gases and aerosols). This is crucial in understanding trends in short-lived greenhouse gases, aerosols, ozone depletion in the stratosphere, acidification and regional air pollution. The course gives an introduction to modelling of atmospheric chemistry in e.g. Earth System Models.

KJM5700

Environmental Chemistry

The course provides an integrated description of the chemical processes and equilibrium systems that determine mobility, transport, turnover and effects of chemical contaminants in air, soil and water. It also provides an introduction to natural chemical processes in the environment. The lectures are given by external and internal researchers with examples from our own current research.

GEO5900

Chemical processes in soil and ground water

The main geochemical reactions controling the chemical composition of soil and ground water are treated in detail, and how these can be quantified and used in interpreting different processes effecting the water quality. Equilibria and kinetics in water-mineral-gas systems are covered, with special emphasis on CO_2 – carbonate reactions, mineral weathering, redox-reactions, ion exchange, sorption, and pollution of organic chemicals. An understanding of these procecces and a corresponding quantification is required to predict the effect of contaminant spill and human influence. Lectures and home works are accompanied by training in computer modeling of geochemical reactions and transport of solutes in groundwater.

BIOS5411

Toxicants in ecosystems and humans: effects

The course gives insight into how toxicants affects humans and the environment, with a particular focus on individual effects. Toxicants affect many of the same processes in different organisms and the course will discuss similarities and differences between different species, using mammalian toxicology as a starting point. The course includes aspects of both ecotoxicology and human toxicology.

BIOS5412

Toxicants in Ecosystems and Humans: Exposure and Accumulation

The course gives insight into how toxicants are distributed in the environment and accumulated by humans and other organisms. The course focuses on mechanisms and processes that are important to understand distribution and accumulation of toxicants and how these processes are affected by other stressors, physiological and ecological adaptations, life history traits and the phylogenetic history of the organism. The course encompasses both different ecosystems, including organisms, and humans.

GEO9915

Ecological Climatology

The course provides an overview of the relationships between climate and ecology, with focus on climate related feedbacks within boreal, alpine and arctic terrestrial ecosystems. Through the program, students will understand the connections and interactions between land and atmosphere, with an emphasis on terrestrial vegetation ecology and dynamic vegetation modeling. The main focus will be on processes at northern latitudes.

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Publications

Peer reviewed articles CBA 2023

A

Aga, J., Boike, J., Langer, M., Ingeman-Nielsen, T., **Westermann, S.**, 2023. Simulating ice segregation and thaw consolidation in permafrost environments with the CryoGrid community model. *The Cryosphere*, 17(10), 4179–4206. *https://doi.org/10.5194/tc-17-4179-2023*

B

Broch, C., **Heuschele, J.**, 2023. Zoobooth: A portable, open-source and affordable approach for repeated size measurements of live individual zooplankton. *Heliyon*, 9(5), e15383. *https://doi.org/10.1016/j.heliyon.2023.e15383*

C

Crapart, C., Finstad, A. G., **Hessen, D. O.**, **Vogt, R. D.**, **Andersen, T.**, 2023. Spatial predictors and temporal forecast of total organic carbon levels in boreal lakes. *Science of The Total Environment*, 870, 161676. *https://doi.org/10.1016/j.scitotenv.2023.161676*

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D

de Wit, H. A., Garmo, Ø. A., Jackson-Blake, L. A., **Clayer, F.**, **Vogt, R. D.**, **Austnes, K.**, Kaste, Ø., **Gundersen, C. B.**, Guerrerro, J. L., Hindar, A., 2023. Changing Water Chemistry in One Thousand Norwegian Lakes During Three Decades of Cleaner Air and Climate Change. *Global Biogeochemical Cycles*, 37(2). *https://doi.org/10.1029/2022GB007509*

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Halvorsen, H. L., Bohlin-Nizzetto, P., Eckhardt, S., Gusev, A., Möckel, C., Shatalov, V., Skogeng, L. P., **Breivik, K.** (2023) Spatial variability and temporal changes of POPs in European background air. *Atmospheric Environment* 299. *https://doi.org/10.1016/j.atmosenv.2023.119658*

Heuschele, J. D., **Andersen, T.**, Walseng, B., **Hessen, D. O.** Assessing climatic and spatial variables influencing zooplankton richness for space-for-time predictions. *Freshwater Biology* 69 (1) pp. 64–73. *https://doi.org/10.1111/fwb.14193*

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Isles, P. D. F., Creed, I. F., **Hessen, D. O.**, Kortelainen, P., Paterson, M., Pomati, F., Rusak, J. A., Vuorenmaa, J., Bergström, A., 2023. Widespread synchrony in phosphorus concentrations in northern lakes linked to winter temperature and summer precipitation. *Limnology and Oceanography Letters*, 8(4), 639–648. *https://doi.org/10.1002/lol2.10318*

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Keetz, L. T., **Lieungh, E.**, Karimi-Asli, K., Geange, S. R., Gelati, E., Tang, H., **Yilmaz, Y. A.**, Aas, K. S., Althuizen, I. H. J., **Bryn, A.**, Falk, S., Fisher, R., Fouilloux, A., Horvath, P., Indrehus, S., Lee, H., Lombardozzi, D., **Parmentier, F. W.**, Pirk, N., Vandvik, V., **Vollsnes, A. V.**, Skarpaas, O., **Stordal, F.**, Tallaksen, L. M., 2023. Climate–ecosystem modelling made easy: The Land Sites Platform. *Global Change Biology*, 29(15), 4440–4452. *https://doi.org/10.1111/gcb.16808*

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Langer, M., von Deimling, T. S., **Westermann, S.**, Rolph, R., Rutte, R., Antonova, S., Rachold, V., Schultz, M., Oehme, A., Grosse, G., 2023. Thawing permafrost poses environmental threat to thousands of sites with legacy industrial contamination. *Nature Communications*, 14(1), 1721. *https://doi.org/10.1038/s41467-023-37276-4*

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Naas, A. E., Halvorsen, R., Horvath, P., Wollan, A. K., Bratli, H., Brynildsrud, K., Finne, E. A., Keetz, L. T., **Lieungh, E.**, Olson, C., Simensen, T., Skarpaas, O., Tandstad, H. R., Torma, M., Værland, E. S., **Bryn, A.**, 2023. What explains inconsistencies in field-based ecosystem mapping? *Applied Vegetation Science*, 26(1). *https://doi.org/10.1111/avsc.12715*

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Conference proceedings

Schultze, S., Langva, H. K., Knudtzon, N. C., Chatzigeorgiou, M., Rundberget, J. T., Brooks, S., Poste, A. E., **Hessen, D. O.**, Ruus, A., Andersen, T., Borgå, K., Terrestrial dissolved organic matter is not an efficent vector for lipohilic contaminants in filter feeders, SETAC conference 2023, Dublin, 30 April-4 May 2023

Vogt, R. D., Austnes, K., **de Wit, H.**, Gundersen, C. B., Diverging trends in Ca and Mg under chemical recovery, 39th meeting of the Programme Task Force of ICP Waters, and the 6th Joint ICP IM and ICP Waters TF meeting, Lunz, 9–11 May 2023

Opdal, A. M. F., Andersen, T., **Hessen, D. O.**, Lindemann, C., Aksnes, D. L., Tracking freshwater browning and coastal water darkening from boreal forests to the Arctic Ocean, ASLO Aquatic Sciences Meeting, Palma, Mallorca, 4–9 June 2023

Jensen, T. C., Schartau, A. K., Majaneva, M., Veraat, A. J., **Hessen, D. O.**, **Eiler, A.**, Bird impacts on biological communities in Arctic ponds, Svalbard Science Conference 2023, Oslo, 31 October-1 November 2023

Lambert, M. S. A., Tang, H., Aas, K. S., **Stordal, F.**, Bjerke, J. W., Fisher, R. A., Fang, Y., Holm, J., Ding, J., **Parmentier, F.-J. W.**, Winter survival of vegetation in the Arctic-boreal region: Integrating cold hardiness and frost mortality schemes into CLM-FATES, American Geophysical Union Fall meeting, San Francisco, USA, 12 December 2023

White, J. D., Ahrén, D., Ström, L., Kelly, J., Klemedtsson, L., Keane, B., **Parmentier, F.-J. W.**, Methane Producing and Oxidizing Microorganisms Display a High Resilience to Drought in a Swedish Hemi-Boreal Mire, C-PEAT Peatland Workshop at AGU, San Francisco, USA, 14 December 2023

Pongracz, A., Wårlind, D., Miller, P. A., Rabin, S., Gustafson, A., **Parmentier, F.-J. W.**, Contrasting trends in snow thickness govern future trajectories of Arctic-boreal carbon release, American Geophysical Union Fall meeting, San Francisco, USA, 15 December 2023

CBA's economy in short

CBA is a centre directly under the Faculty of Mathematics and Natural Sciences, and financially supported by the Faculty via the three involved institutes: Biosciences, Chemistry and Geosciences, initially for a period of five years from 2018. This amounts to 500 000 NOK per institute and covers the salary costs of a centre coordinator, a PhD student and a postdoctoral researcher directly employed by CBA, in addition to some running costs. Other CBA researchers are employed at the departments of biosciences, geosciences and chemistry. On top of these basic grants come project grants from the Research Council of Norway, EU and other sources, plus 2–3 PhD-positions ("KD-stipendiater" from the Faculty.

The economic model of CBA is based on a shared division of overhead from external projects, where 60% of overhead is assigned to the respective institutes and 40% is allocated to CBA. Thus over time the direct faculty support will be replaced by such overhead costs from externally funded projects. CBA runs, or is part of, several such externally funded research projects, some of which are presented through this report.

Starting from September 2022, CBA has received funding from the Norwegian Research Council (RCN) for the project "Biogeochemical processes Governing boreal C cycling" (BioGov), with a total budget of 25 mill NOK. This project will run until 2027 and include a major fraction of the permanent staff at CBA in all three institutes. Also, several PhD-students and postdoctoral researchers will be hired under this project, and many master students are affiliated with budget allocations from the respective departments. The RCN-funded project IMPACT started in 2023 and the ERC-funded project ACTIVATE will start in early 2024. Both projects run jointly within CBA and their respective host institutes. Increased costs at the Faculty and the UiO-levels may over time indirectly affect CBA as well, which motivated for intensified grant applications.

Centre for Biogeochemistry in the Anthropocene

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