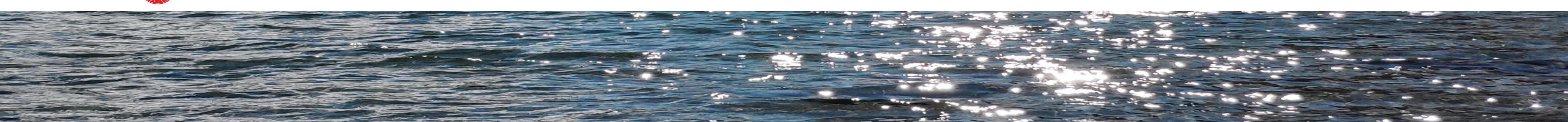
ANNUAL REPORT 2020

Centre for Biogeochemistry in the Anthropocene

UiO : University of Oslo



I N D E X

INTRODUCTION

RESEARCH

ABOUT CBA

Editors-in-chief:
Lene Liebe Delsett & Jan Heuschele
Cover page: Skaupsjøen / Hardangerjøkulen glacier
Image credit: Nicolas Valiente Parra

MISSION

We study interactions and feedbacks between climate, carbon cycling and ecosystems in northern latitudes
We assess and predict changes in global carbon cycling, which is a crucial requirement to develop strategies to counter anthropogenic climate change.

We educate the next generation of climate scientists in the fields of biology, chemistry and geology.
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 cutting-edge science to understand biogeochemical cycles in a changing anthropogenic world.
- to develop strategies to help society and ecosystems reverse or adapt to climate and environmental changes.

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

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.

The leader group
Dag O. Hessen, professor in biosciences is the centre leader
Rolf David Vogt, professor in chemistry
Frode Stordal, professor in geosciences – until June 2020
Terje Koren Berntsen, professor in geosciences – from June 2020

The board
Brit Lisa Skjelkvåle, head of Department of geosciences and CBA board leader
Rein Aasland, head of Department of Biosciences
Einar Uggerud, head of Department of Chemistry
Solveig Kristensen, vice dean for research, Faculty of Mathematics and Natural sciences
and the leader group

The scientific advisory group
Tim Lenton, University of Exacter, Global Systems Institute
Marten Scheffer, Wageningen University of Research
Vigdis Vandvik, Bjerknes Centre for Climate Research, University of Bergen

Centre coordinator
Jan Heuschele was the centre coordinator from the start of CBA until May 2020, when he moved on to a researcher position at UiO. Lene Liebe Delsett took over as the new centre coordinator.

CLIMATE, CORONA, AND TIPPING POINTS

Dag O. Hessen
Professor in Biosciences & Leader of CBA

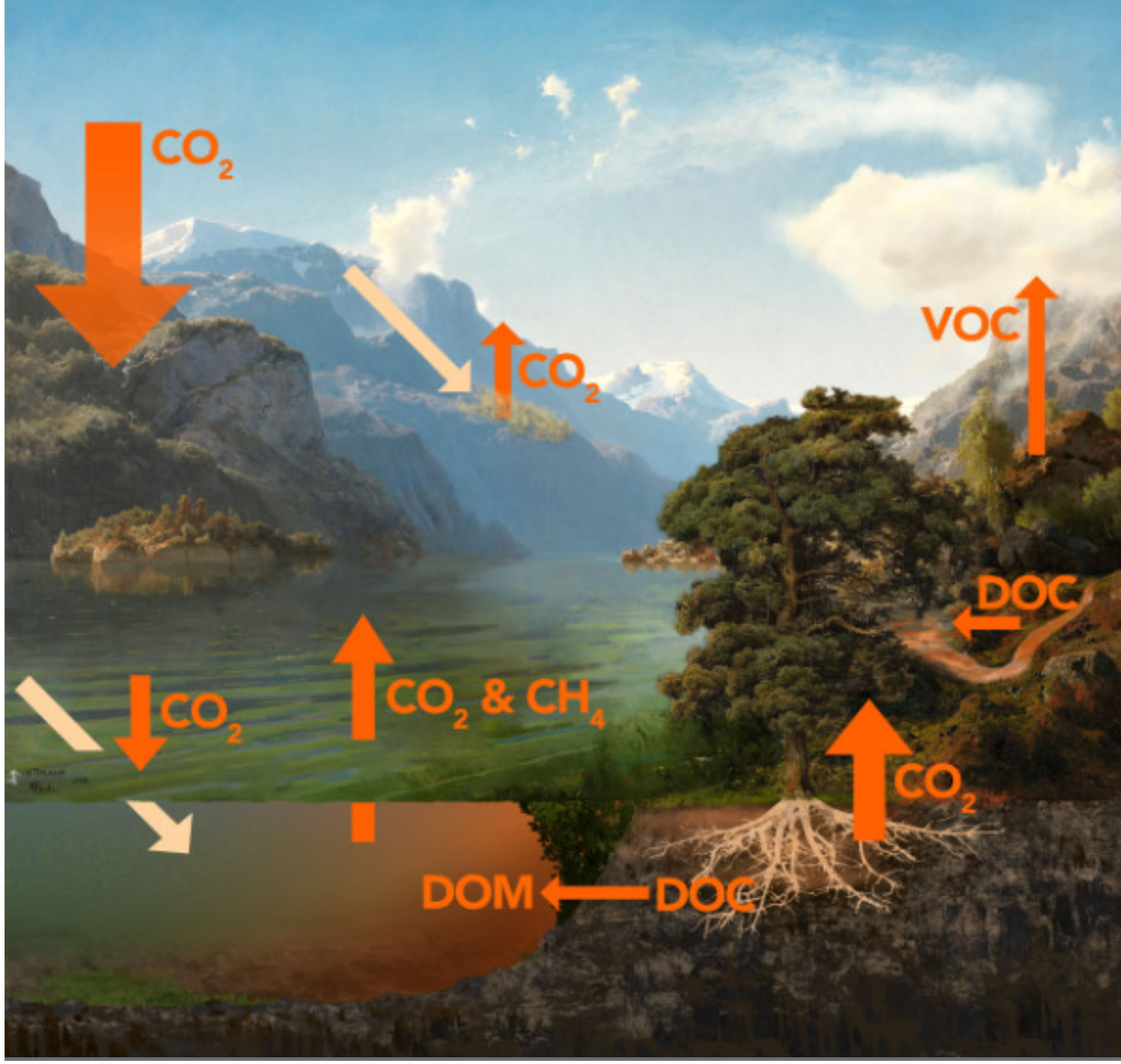
The Centre for Biogeochemistry in the Anthropocene (CBA) entered 2020 in good pace – and then we were hit by Corona – as everybody else. As for the rest of the society, the consequences varied from modest to major. For the Master's students, PhDs and Postdocs who were just at the starting point of their projects, or just had arrived Norway when universities closed down at March 12, the effects have been severe. While some remedies have been taken, contacts and lectures have been digitalized and extensions given wherever possible, this has clearly not compensation for all drawbacks. Because CBA is distributed over three different departments and different research groups, the seminars and meeting places serves as an important glue – and these activities have suffered. Still, there has been an impressive amount of work done during 2020, as this annual report and list of arrangements and scientific outputs will witness.

The CBA activities cover a range of scales in space and time, from molecular and genomic processes in microbial communities to large scale regional or even global models related to climate forcing and climate responses in northern regions (covering atmosphere, tundra, boreal forests, wetlands, lakes and coastal areas). The idea behind CBA is thus to merge scales, projects, people and ideas since the complex problems involved in climate, elemental cycling and feedbacks no doubt requires a broad multidisciplinary effort. CBA should thus provide an added value and both deeper and broader insights.

Many people have been involved in field activities, and a highlight in this context was the integrated sampling at Finnmark in fall, including the permafrost sites at Iškoras, where many people participated, thus fulfilling some of the key goals of CBA. A more thorough presentation of this is provided in the report. There has also been an impressive list or scientific papers provided by CBA-related researchers in 2020, several in top-ranked journals. The full list is to be found later in this report.

An important delivery from CBA is education, and the joint course in biogeochemistry that was first held in 2019 was very well attended and received also in 2020. Last but not the least, CBA should be actively engaged in dissemination, public debates and even political debates, popular science writing, public lectures and thus be involved in setting the agenda on relevant issues related to climate, CO_2 sequestration and greenhouse gas release in natural systems, northern ecosystem processes and the risk of feedbacks or even tipping points from these systems. A large number of talks, popular outreach and books can also be found in this report, witnessing that CBA already takes this task seriously.

Biogeochemistry is a complex and, to many, unknown field. It is truly interdisciplinary, covering physical, chemical, geological and biological process across systems and scales. A proper understanding these processes is imperative for understanding climate drivers and responses, the resilience and robustness of natural



The carbon cycle in a Norwegian context (Painting by Adolph Tidemand & Hans Gude modified by Jan Heuschele

systems and thus the risks we are facing in the Anthropocene. Central to this is the risk of feedbacks, abrupt changes or even tipping points. The annual and very well attended CBA lecture in late fall 2019 by Tim Lenton, member of the CBA scientific board, addressed exactly these points under the topic "Climate tipping points". This year another scientific board member, Marten Scheffer, presented the annual lecture digitally on the really big picture of tipping points entitled: "Ancient civilizations transformed when they reached a tipping point. Are we on the same track?".
This against brings us back to Corona. It has become harder to tell what the future will bring also in this context. The feeling of tipping-point times have become even more pressing (read also article on page 36). We have just passed the five-year anniversary for the Paris agreement, and while there indeed are positive signs and winds of change in society at large, including the finance and business sector, we are currently heading towards a 3 °C temperature increased by 2100. As very many has pointed out, we are now in a state where we need to use research and scholarly insights to push change in the right direction, and CBA should help motivation this transition. It is thus a great inspiration, and gives a sense of meaning, to be part of this. We look all forward to 2021 and the years to come.

A WORD FROM SCIENTIFIC ADVISOR TIM LENTON

Director Global Systems Institute
University of Exeter

It is great to see the progress of the Centre for Biogeochemistry in the Anthropocene over the extraordinary last year of the global pandemic. Whilst our human movements were restricted the great movements of the carbon cycle carried on unawares, and the rise of global temperatures continued to perturb them. Amidst all of this, the Centre has achieved an impressive and diverse range of outputs – from critical insights into how changing cloud feedbacks could radically increase global warming, to new connections from dissolved organic matter flows off the land to cod spawning times in the ocean. The discovery of these new connections and feedbacks give us all a better understanding of the Earth system. That in turn is crucial for us to be able to successfully navigate the turbulent waters of the Anthropocene. The pandemic has been an unexpected test of our societies and institutions – and one that the CBA has passed with flying colours. But it is unlikely to be the last unpleasant surprise we face together. The CBA's commitment to studying our life-support system and teaching others about it is only going to get more important in the years ahead.

Lake in the Iškoras region, *Photo by Nicolas Valiente Parra*

FRESHWATER BIODIVERSITY IN A CHANGING ARCTIC: FROM GLACIERS TO THE FAR NORTH

Nicolas Valiente Parra
Department of Biosciences

Lake close to Hardangerjøkulen (Photo by Nicolas Valiente Parra)

Roavatjohka river close to Kautokeina (Photo by Nicolas Valiente Parra)

From 2019, researchers from the USA, Canada, Sweden, Denmark and Norway are developing a cooperative effort to fill gaps in Arctic freshwater biodiversity knowledge. This project (ARCTIC-BIODIVER: Scenarios of freshwater biodiversity and ecosystem services in a changing Arctic) encompasses the study of a huge number of high Arctic ponds and lakes. ARCTIC-BIODIVER is granted from both Belmont Forum and The Research Council of Norway and is led by Dag O. Hessen on the Norwegian side.

In August 2019, our CBA researchers made their first contact in ponds from Svalbard and Finse. In 2020, when Covid-19 allowed it, it was the time to go deeper into the Hardangerjøkulen glacier (Finse) and travel to the northern tip of Scandinavia (Finnmark). Both campaigns included the collection of samples to analyze pH, nutrients, dissolved organic carbon, chlorophyll, zooplankton, phytoplankton, eDNA, stable isotopes and dissolved gases (inc. greenhouse gases CO_2, CH_4 and N_2O).
The Finse area, supported by the Finse Alpine Research Center (60° N; 1222 masl), is well known by many researchers of the CBA (e.g. LATICE project). Sampling of ponds and lakes was conducted from along a transect from Hardangerjøkulen glacier front to the vicinity of Geilo (Viken), to incorporate into the study the influence of the glacier retreat. The preliminary data show how microbial diversity changes with increasing distance to the glaciers and changes of nutrient status, reflecting the outcomes of ecological succession.

Iškoras close to Karasjok (Photo by Nicolas Valiente Parra)

Afterwards, our CBA researchers travelled to Alta (Finnmark) to conduct an intense 9-day fieldwork campaign. More than 20 sites were chosen to be monitored along almost 500 km from southern Kautokeino (69° N), in the northern tip of Finland, to Vardø (70° N), at the eastern end of the Varanger peninsula. During this trip, there was not only time to monitor biodiversity in lakes and rivers, but also to visit the area of Iškoras (Karasjok), being possibly the most iconic coordinated trip of CBA researchers during 2020. This area is affected by thermokarst processes, leading to form ponds of high microbial activity. In collaboration with CBA researchers, as well as NMBU researchers, permafrost samples were collected for further incubations. Permafrost thaw is one of the most concerning "tipping points" in the Arctic, and therefore it is important to improve our understanding of community composition and ecosystem change from a microbial perspective.

These fieldwork campaigns not only have provided a breath of fresh air in a difficult year, but also have undoubtedly served as a valuable experience for next summer by increasing our knowledge of the changing Arctic and strengthening interdisciplinary work within the CBA.

Sesvolltjernet, Eidsvoll .
Photo by Nicolas Valiente Parra.

LINKING MICROBIAL COMMUNITIES TO LAKE METABOLISM

Alexander Eiler
Department of Biosciences

While boreal lakes are numbered in the millions and important contributors to greenhouse gas emissions to the atmosphere, the microbial systems catalyzing chemical transformation processes are widely unknown. In the current project we perform detailed 'meta'omics analysis along redox gradients and combine the molecular data with chemical measurements across numerous lakes representative of the boreal landscape. The genomic data has already revealed the presence of iron- and sulfur-oxidizing phototrophs and chemolithotrophs as well as methanotrophs in the anoxic portion of the studied boreal lakes. Chemolithotrophic and anoxygenic photosynthetic genomes predict the potential for active sulfur and iron cycling likely driving greenhouse gas emissions. As a next step we will perform experiments and model the contribution of anoxygenic photosynthesis, methane and nitrogen cycling to ecosystem metabolism in the diverse lakes and their role in future greenhouse gas emissions.

We are now waiting for spring to finalize our annual sampling of six lakes. Winter sampling has been a success with multiple high-resolution depth profiles already under analysis.

Sampling at Sesvolltjern during summer and winter. This lake is characterized by extremely high iron concentrations (2.9 mg l-1) and an average of TOC (5.8 mg l-1), thus a good spot to hunt for photoferrotrophs. Photoferrotrophs thrived in the Archean Ocean and are hypothesized to have been the Earth's early primary producers driving life billions of years ago. As remains of ancient photosynthesis they may give insights into early evolution of photosynthesis and the appearance of oxygenic photosynthesis. Photoferrotrophs may still play an important role in iron-rich boreal lakes driving iron-oxidation and thus oxidized-iron dependent processes such as anaerobic respiration and methane oxidation.

1000, 80, AND 5 LAKES...

Dag O. Hessen
Department of Biosciences

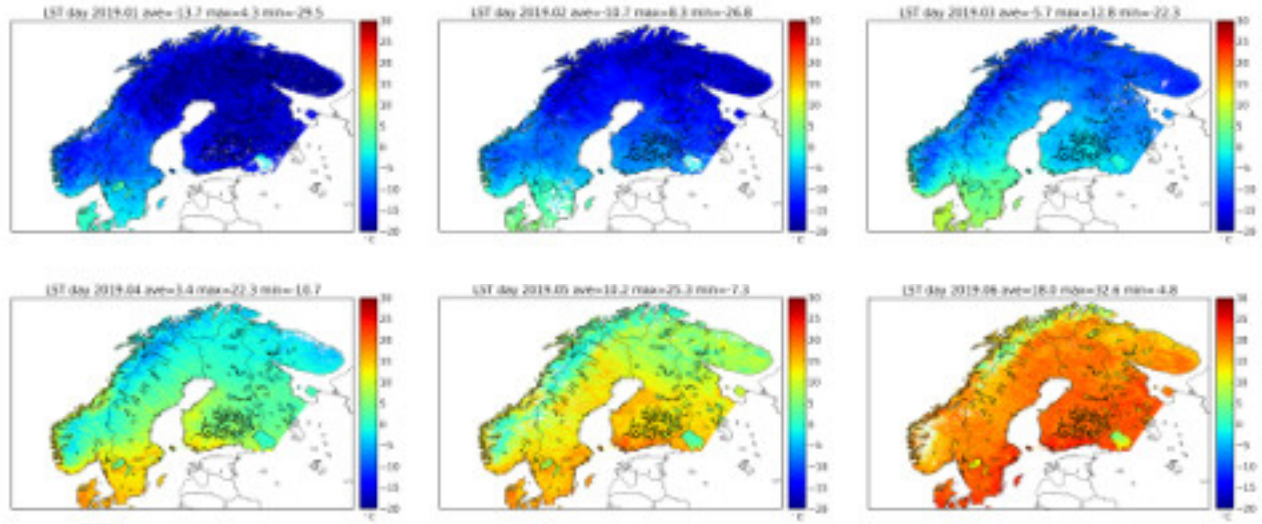
Lake close to Hardangerjøkulen. Photo by Nicolas Valiente Parra

In the vast, northern, boreal forests the processes on land are also major determinants of the properties of lakes, rivers and coastal ecosystems. Carbon as CO_2 is taken up by vegetation, and forests stores C in biomass and soils. A fraction of this C enters surface waters as dissolved organic carbon (DOC), providing a distinct brown staining. DOC reduced transparency and thus primary production, and also provide substrate for production of CO_2 and CH_4. Thus, lakes and rivers are important for processing and cycling carbon, and important conduits of greenhouse gases.

Lakes and rivers may serve as sentinels of terrestrial process, not only in terms of C, but other key elements line nitrogen, phosphorus, calcium, silicate, iron, sulfur and others. They also provide information about anthropogenic impacts such as acidification, elevated nitrogen deposition, application of fertilizers and land use. In 1986, a large number of lakes was sampled and analyzed for a wide range of water quality parameters, and in 1995 this was extended in a nation-wide "1000 lake survey" in concert with other Nordic countries where additional thousands of lakes were sampled. In fall 2019 these 1000 lakes were again sampled by Norwegian Institute for Water Research in a synoptic survey by helicopters, offering a unique opportunity to check for changes in water quality.

As a subset of these, we aimed to sample 80 lakes for additional parameters, not the least eDNA and greenhouse gases (see text from Nicolas Valiente Parra in this report), and as a subset of these again we selected a subset of 5 lakes that we follow on a seasonal basis, also covering additional data to get a deeper understanding of temporal and spatial relations between microbial communities, water quality parameters, bacterial greenhouse gas production and also other metabolic properties of the microbial communities during the year (see text by Alexander Eiler).

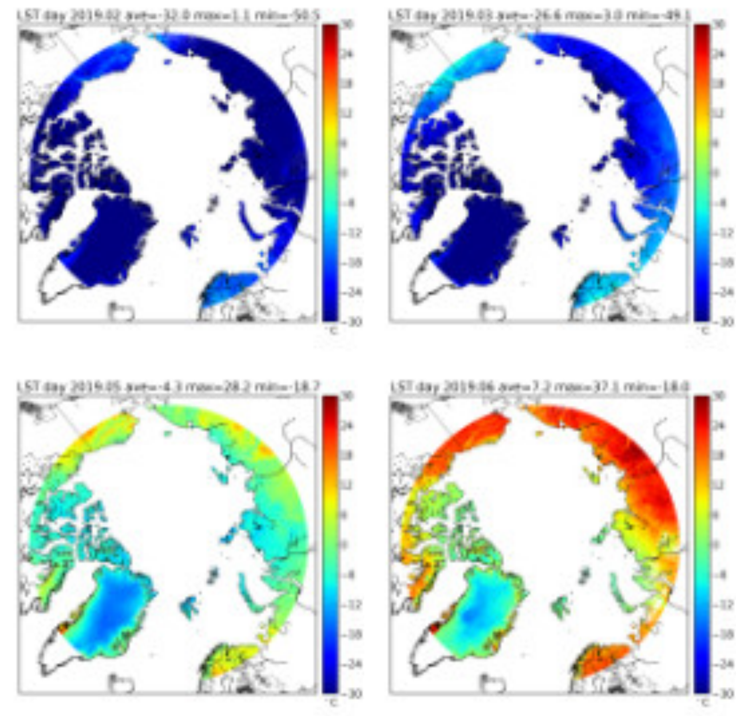
Altogether, these data offer new insights into changed water quality of northern freshwaters, how this s linked to climate and terrestrial processes, and how this may feed back to the atmosphere and climate systems.



PROBING TRENDS OF ENVIRONMENTAL CHANGES WITH MODIS SATELLITE REMOTE SENSING

You-Ren Wang
Department of Biosciences

MODIS remote sensing products provide valuable data for assessing trends of environmental changes from year 2000 onwards with global coverage and fine spatial resolution. Among all the products, I am in particular interested in LST (Land Surface Temperature) and NDVI (Normalized Difference Vegetation Index) data, as they have the potential to reveal physical and biological trends of evolution in the past two decades worldwide. The study is still ongoing, and above and to the right you see some of the LST data maps for the Fennoscandia and the Arctic.



THE GREEN SHIFT: DAMNED IF YOU DO, DAMNED IF YOU DON'T?

Heleen de Wit
NIVA

The green shift has the lofty aim to transform societies towards a more circular bio-based economy, from use of fossil fuels towards renewable resources. The EU and the Nordic countries view this as absolutely key to achieving a more climate-friendly and sustainable society. This implies – among others - an increased demand for biomass production, which is, in a Nordic context, by and large expected to come from forests (Marttila et al. 2020).
While avoiding deforestation is perhaps the biggest land-use related challenge for tropical rainforest and for the planet as a whole, afforestation on marginal agricultural land for climate mitigation purposes is an official strategy in Norway (Haugland et al., 2013). In management strategies, forests are thus being viewed as instruments for carbon storage, but also as sources of organic carbon to replace fossil fuels. However, it is difficult to manage forests both for maximizing carbon storage and for production of fuelwood. To assess strategies for using forests for climate mitigation, the return time of carbon back to the atmosphere key (Holtsmark 2013; Holtsmark 2015). Return time, or turnover time (Carvalhais et al. 2014) can be estimated as pool size divided by flux (input or output per time unit). Biomass used for production of biofuels will return to atmospheric CO_2 more quickly than timber used for building houses. However, forests are of course more than instruments for carbon storage or producers of timber. Forests are habitats for insects, birds, mammals, destinations to walk and camp, fish and hunt and retainers of excess rainwater which prevent flooding. Thus, forests are important to Nordic societies in many ways beyond their capacity to store atmospheric carbon.
Afforestation will lead ultimately lead to mature or old forest (Framstad et al. 2013), unless it is harvested, burned or is killed by insect attacks or thrown down by wind - where the stored carbon in trees can be mobilized back to the atmosphere by forest fires or possibly remain in the forest as dead wood from windfalls, slowly decaying and thereby releasing CO_2. However, the natural carbon cycle is a much slower cycle than the cycle by which biomass used for biofuels is returned to the atmosphere. Thus, to what extent forests can mitigate increases of atmospheric CO_2 ultimately depends on the duration of locked atmospheric CO_2 in 'safe storage'. A safe way to lock down atmospheric carbon is in soils at northern latitudes. Carbon in soils in northern forests as a turnover time of 250 years, compared with vegetation which has a turnover time of less than two decades (Carvalhais et al. 2014; Knorr et al. 2005).

Soil sampling in the pasture. The planted spruce forest is viewed in the background (Photo by L.T. Strand).

Sampling the soil from the forest (Photo H. de Wit)

Forest soils are rich in carbon in northern forests – far richer than in agricultural soils (Strand et al. 2016). Thus, it seems reasonable to assume that planting of forest will lead to increased carbon storage in soils. It is surprisingly difficult to find studies that provide simple evidence for this assumption. This is in part because carbon accumulation in soils is notoriously difficult to study: soil carbon accumulation rates are slow, soils are heterogenous and soil sampling is destructive: there is no going back to exactly the same place to measure change over time in the same way you can with trees. Eddy covariance towers such as those used at CBA-sites Finse and Iškoras (measuring land-atmosphere exchange of CO_2) are helpful, but don't present the entire answer: the fluxes that are measured do not differentiate between vegetation and soils, and they need to be corrected for lateral export of carbon from soils to water.

In a recent study (Strand et al. 2021), we found a seldomly used opportunity to test effects of afforestation: neighboring fields with different owners were very similar in soil properties but had a different land use history. On one field, spruce forest had been planted in 1967 while on the other field, grazing had been continuously practiced since before 1967. Soil samples were taking according to well-established principles, 50 years after planting. We expected in increase in soil organic matter stock, given the large increase in litter addition to the soil from the forest. However, no such difference was found. Our explanation is that a higher bulk density in the pasture, from grazing cattle, has led to higher soil moisture and less favorable conditions for degradation of organic matter.

Sampling the soil from the pasture (Photo H. de Wit)

Another factor that matters to evaluate the effect of afforestation on climate is the albedo effect: in regions that have seasonal snow cover, forests reflect less solar radiation than tundra or grassland (de Wit et al. 2014).

Returning to the green shift, where forests are presented as important instruments to move towards more sustainable and climate-friendly societies, it is tempting to conclude that afforestation hardly seems effective.

However, forests in the Nordic countries have increased in biomass in the past fifty to a hundred years and in Norway, have compensated for circa 30% of anthropogenic CO_2 emissions (de Wit et al. 2015). Increased forest growth is partly rebounding from intense use of forest resources in the start of the 20th century while climate warming and nitrogen deposition may have also stimulated forest growth. Still, intensification of forestry cannot be done without some costs for the environment (e.g. (de Wit et al. 2020)).

The larger issue at hand, of course, is how to balance the ways that we use our environment – avoiding ecosystem degradation while mitigating climate change. The longer term answer appears to be that people and societies should reduce their environmental footprint and substitute reliance on fossil fuels with renewable energy sources. One of the shorter term answers that Nordic societies provide is the green shift. Damned if you do, and damned if you don't? A more integrated approach to study effectiveness of climate mitigation in relation to forests could be provide some necessary answers to these complicated questions.

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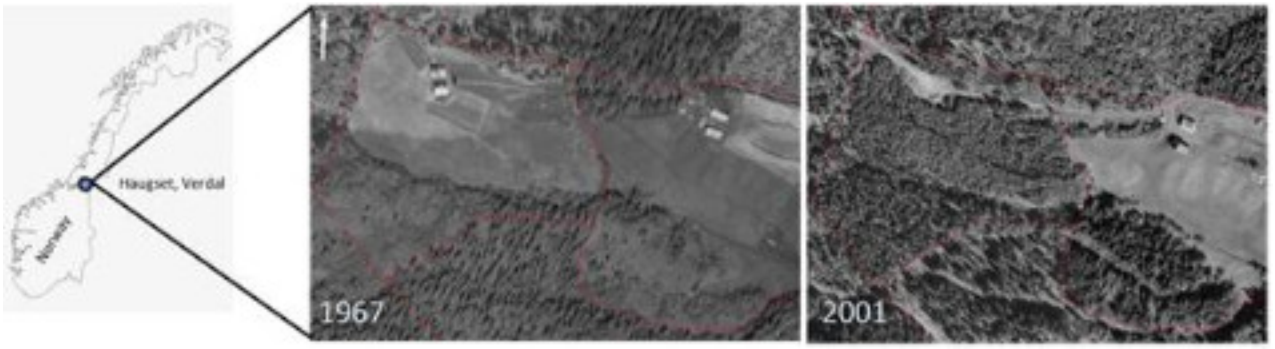

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THAWING PERMAFROST PEATLANDS

Sebastian Westermann
Department of Geosciences

Permafrost peatlands are wide-spread features throughout the sub-Arctic and contain large amounts of organic carbon. In Northern Norway, permafrost peatlands are thawing strongly, so that we can directly observe the impact of permafrost thaw on the carbon balance. In September 2020, we conducted fieldwork at three peat plateau sites in Finnmark. We collected a number of cores from both the active layer and the permafrost for analysis at the Norwegian University of Life Sciences (NMBU). The laboratory work includes incubations under both oxic and anoxic conditions to investigate the degradability and greenhouse gas production potential of the permafrost material. It is part of the MSc theses of Sigrid Kjær Trier and Nora Nedkvitne

Field work participants: Nora Nedkvitne, Sigrid Kjær Trier, Peter Dörsch (all NMBU), Sebastian Westermann (UiO)

Sampling in Finnmark. Photo by Peter Dörsch.

WINTERPROOF

Frans-Jan Parmentier
Department of Geosciences (UiO) / Department of Physical Geography and Ecosystem Science (Lund University)

One of the potentially largest climate feedbacks in the Earth system is a release of carbon from the Arctic to the atmosphere. This high northern region is the fastest warming part of our planet, and this can alter the carbon uptake by vegetation and increase the release of greenhouse gases from permafrost soils. These biogeochemical processes may be particularly influenced by autumn and winter weather conditions, since this part of the year experiences the strongest warming. To illustrate: warmer air temperatures lead to a delay in the freezing of soils, which prolongs the activity of microorganisms that respire carbon into the atmosphere. Also, extreme winter events, such as rain-on-snow, have been on the rise in recent years and these intrusive events can lead to extensive vegetation damage. This reduces photosynthesis and net carbon uptake in the following summer. The amplified warming of the cold season affects biogeochemical processes that can cause a net increase in the release of greenhouse gases from the Arctic to the atmosphere.

Biogeochemical process models fail to make reliable projections of these perturbations of the carbon cycle, despite the large potential for change due to the large carbon stocks stored in arctic soils. This limits our ability to project arctic carbon release into the future, and to assess the strength of this climate feedback. In the CBA, we tackle this problem under the umbrella of the WINTERPROOF project, a collaboration between the University of Oslo and Lund University in Sweden.

This project, funded by the research councils of Norway and Sweden, supports two PhD students: Marius Lambert in Oslo and Alexandra Pongrácz in Lund. Marius focuses on wintertime damage to vegetation, and how this links to the greening and browning of arctic ecosystems. Alexandra studies how winter conditions influence the release of greenhouse gases from permafrost soils.

So far, the project has shown that an improved representation of snow is paramount to not only correctly simulate soil temperatures and permafrost extent, but also to achieve realistic soil biogeochemistry and vegetation distribution. Moreover, by using the latest plant hydraulics scheme, we have been able to show that deeply frozen soils can induce plant mortality through root water loss. For the remainder of the WINTERPROOF project, we aim to further improve the transfer of greenhouse gases from soils to the atmosphere, to implement survival strategies by plants to extreme cold, and to explore the role of winter warming on the arctic carbon cycle under current and future climate change scenarios.

Browning pine tree needles.
Photo by Frans Jan Parmentier

THE DOUBLE PUNCH: OZONE AND CLIMATE STRESSES ON VEGETATION

Ane Vollsnes
Department of Biosciences

Vegetation is being hit by a double punch; air pollution and climate change. Ground level ozone is a problem reducing yield and growth of plants in natural vegetation all over the world. In our project, the effects of Arctic conditions with midnight sun are examined, as there are indications that lack of nighttime darkness can enhance the ozone sensitivity of the plants. We use experimental equipment for exposing plants to ozone under controlled environment conditions, making us able to describe and quantify the effects of ozone on the plant species of interest. We have found that ozone affects the fungal community around the roots, including mycorrhiza, which is important for mineral nutrient uptake in the roots. One important goal for our work is to model plant responses to ozone exposure at high latitudes more precisely. In the field, we have done measurements of photosynthesis and transpiration rates for parameterization of vegetation for model work. We have chosen to place emphasis on studying diurnal variations in plant activity in the field during the midnight sun period. Through climate modelling, we have found that the levels of tropospheric ozone in Northern Scandinavia during the summer of 2018 were 5-8 % higher than expected from the climatology. Currently, we are investigating how large the combined effects of climate and ozone may have been on the vegetation in 2018 and 2019.

People working in the project:
Ane V. Vollsnes (BIO), Stefanie Falk (GEO), Aud B. Eriksen (BIO), Frode Stordal (GEO), Terje K. Berntsen (GEO) and Håvard Kauserud (BIO)
Master student: Åshild F. Kapperud (NHM/BIO).

Normal *Trifolium repens* leaf

Ozone damaged *Trifolium repens* leaf

Photo by Irene Davila on Unsplash

HIGHER CO_2 AND LOWER PLANT QUALITY

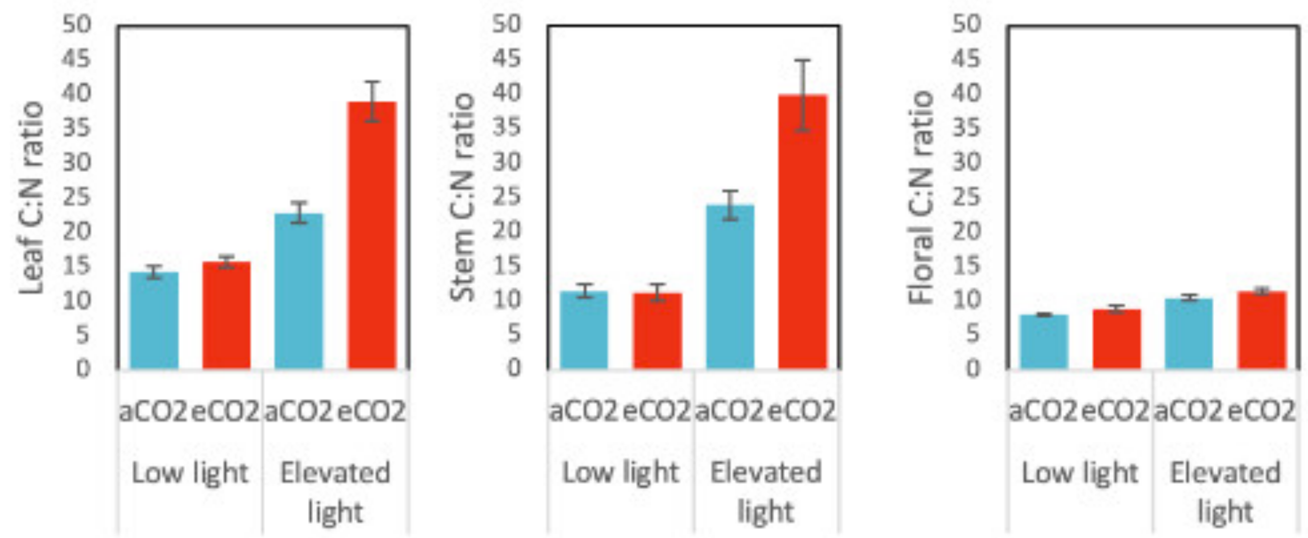
Christina Seljebotn, Anne Hope Jahren, William Hagopian, Ane Vollsnes and Dag O. Hessen
Department of Biosciences & Department of Geosciences

Elevated CO_2 not only act as a greenhouse gas and an agent of ocean acidification, it is also an essential plant nutrient constituting nearly 50 % of plant dry-weight. Plants are typically subsaturated on CO_2 and the potential CO_2-fertilization effect (CFE) has thus gained considerable interest and also led to the misconception that more CO_2 is beneficial to ecosystems and society. An enhanced plant productivity also serves as an important negative feedback on atmospheric CO_2 and climate warming (Friedlingstein et al. 2019), but there are now clear signs of a slowing down of this CFE (Wang et al. 2020). This may partly be related to increased temperature and hydrological stress, but also the fact that over time vegetation needs a balanced supply of various elements. With continued CO_2-enrichment there will be shortage of other elements causing skewed elemental ratios. This again may cause a stoichiometric mismatch across the plant-herbivore boundary. In brief, this means that while herbivores may have access to plenty of plant mass, the growth efficiency or even the growth rate may decline because of relative shortage of P (to build nucleic acids, notably ribosomes) or N (to build proteins). In other words, there is a situation with C in excess to herbivores, in which less C is diverted into somatic growth or reproduction, and more C is excreted or respired (Hessen and Anderson 2008; Hessen et al. 2013). Increased release of CO_2 and organic C by roots will also promote weathering as well as increased flux of dissolved organic C to soils and water, thereby causing a widespread "browning" of surface waters in boreal areas (Finstad et al. 2016). Thus the CO_2-mediated responses in vegetation have widespread ecosystem consequences for cycling of C and other elements, and links atmosphere, biosphere, lithosphere and hydrosphere together.

Since plant matter typically has somewhat lower concentration of N and P than animal tissue, the trophic efficiency is often low for herbivores, but will likely be further reduced if elevated CO_2 promotes even more protein-poor plant matter (Cotrufo et al. 1998; Taub et al. 2007). Elevated CO_2 also skews C:P ratios, which may be detrimental to herbivores that frequently face dietary N- or P-limitation. Increased CO_2 may thus have profound impacts on the flow of energy and productivity across ecosystems. In addition, protein-rich structures like pollen may be particularly susceptible to C:N imbalance, and thus affect pollinators and pollen feeders by reduced protein content in their diet (Ziska et al. 2016). Indeed, comparisons with herbarium specimens as well as experimental studies demonstrated a strong correlation between ambient CO_2 and C:N of plant floral tissue, with almost a 40 % decrease in N relative to C and protein content from 280 to 400 ppm CO_2 based on herbarium samples, a trend that was confirmed and extended to 500 ppm in experimental studies (Ziska et al. 2016).

These trends have raised concerns that elevated CO_2 may also negatively impact human nutrition. Elevated CO_2 effects on plant quantity (productivity and total biomass) have been extensively studied and show higher agricultural yields for crops, including wheat, rice, barley, and potato, given sufficient nutrient supplies. However, CO_2 effects on plant quality, notably protein content, is also a concern for human nutrition (Zhu et al. 2018), as for domestic and wild herbivores. In C3 plants (e.g. rice, wheat), elevated concentrations of CO_2 reduce N and thus protein concentrations, and can increase the total nonstructural carbohydrates, mainly starch and sugars. In addition, lowered levels of essential vitamins and micronutrients have been demonstrated (Loladze 2002, 2014).

We tested this in a recent masters project, where plant growth chambers were set up to grow *Arabidopsis thaliana* under ambient (~400 ppm) and elevated (~700 ppm) CO_2. The chambers made it possible to monitor and adjust CO_2 levels precisely while also tracking the light, temperature and relative humidity. Two separate experiments were run; experiment 1 with saturated (~170 μE) light and experiment 2 with increased (~350 μE) light to test the effects of elevated CO_2 and light on plants. We weighed the plants and analysed the tissues for chlorophyll, C, N and P levels to test if there was a correlation between CO_2, light and element composition. With elevated CO_2, the average dry shoot biomass was reduced in both experiments. The clearest changes were between experiments, biomass and C increased, and N, P and chlorophyll decreased with elevated light. When adding elevated CO_2, the trends were even more profound. This resulted in a large increase in the C:P and C:N ratios. The results largely suggest that elevated CO_2 together with the corresponding changes in climate have a clear effect on the element composition of plants. The effect of elevated CO_2 and light on plant quality (nutrient and protein content) could have negative impacts on small and large herbivores - and humans.



The C:N ratio of leaves, stems and flowers of Arabidopsis plants cultivated under ambient (aCO₂, 400 ppm) or elevated CO₂ (eCO₂, 700 ppm) and low or elevated light intensities (170 or 360 μmol m⁻² s⁻¹, respectively).

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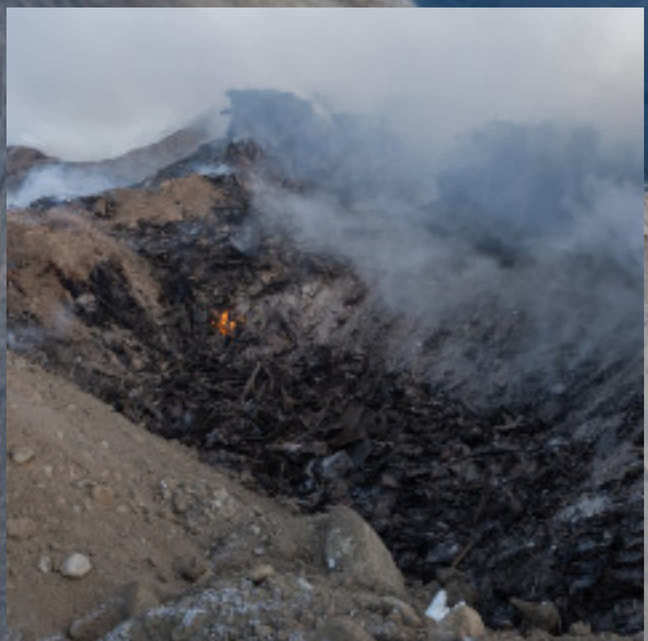
SWEFIRE

A waste storage site at Botkyrka, Sweden had caught fire and thousands of tons of unsorted construction waste had been burning for weeks. There was a concern that the smoke could contain highly toxic organic compound, thus the Swedish authorities requested UiO's Atmospheric Chemistry Group to analyze the chemical content of the smoke.

Alexander Håland (CBA PhD-student, left) and Felix Piel (Postdoc, right) posing with the group's new mobile PTR-ToF-MS laboratory.



Over 100 000 tons of unsorted waste had been burning since 23 of December, 2020.

For safety reasons, the Swedish authorities had prohibited access to the area in the immediate vicinity of the fire.

In addition to real-time analysis with the mobile laboratory, we also collected samples of the smoke for further analysis at UiO.

LAND SURFACE MODEL DEVELOPMENT AT CBA

Kjetil Aas, Terje Berntsen and Hui Tang
Department of Geosciences

Earth System Models (ESMs) are our primary tool for projecting future climate change. They integrate the atmosphere, ocean, land surface and ice, and trace heat, water, carbon and nitrogen as it moves through the different spheres. A major component of ESMs is the Land Surface Model (LSM), which has developed from simply providing energy fluxes to the atmosphere in the 60's and 70's, to today's complex models with advanced vegetation, soil, river and urban representation (Fig. 1). This massive development of LSMs reflect the important and complex role that the land surface plays in the Earth's climate system. However, many of the unique features of the Arctic region is still poorly represented and needs further development.

In CBA, we work to develop the land component of the Norwegian ESM (NorESM), which is the Community Land Model (CLM). This model, which has often been at the forefront of LSM development, is primarily developed at the National Center for Atmospheric Research (NCAR) in the US, but with a broad community working on developing different aspects of the code. Here members of CBA work together with collaborators at NCAR to assess and improve the processes that are particularly important in Arctic and alpine regions.

On the vegetation side, the CBA (through the NFR funded EMERALD project) is working on adding specific representation of moss and lichen, which have currently just been treated as "Arctic grass" in CLM. As the carbon is transferred from the above ground to the soil, CBA members are developing a new soil carbon decomposition model that explicitly represent the interaction between plants and mycorrhizal fungi, replacing a much simpler turnover-time-based soil carbon model. Finally, through the GreenBlue project, the CBA is working to add representation of dissolved organic matter (DOC) to trace leaching of soil carbon through the river system to the ocean, which is an entirely new feature in CLM.

Other CLM related efforts at the CBA includes testing and improving the snow and permafrost components of the model. The highly heterogeneous nature of the cryosphere is currently poorly represented in LSMs, and CBA (through LATICE and EMERALD) is testing the model at field sites and on a regional scale, utilizing field observations and high-resolution remote sensing products. This will eventually lead to better representation of snow and permafrost, which are both involved in important feedback loops in the climate system.

Finally, through collaboration with the National History Museum in Oslo and University of Bergen (Prof Vigdis Vandvik and her group) and Norwegian Institute of Nature in Tromsø (Dr. Jarle Bjerke and his group) we have set up a user-friendly one-dimensional version of the model to allow easy comparison with field data from Norwegian sites. This novel modeling platform brings together climate modelers and field ecologists in a new way, making it possible to draw upon the experience in the different groups of the CBA center and external collaborators in a completely new way.

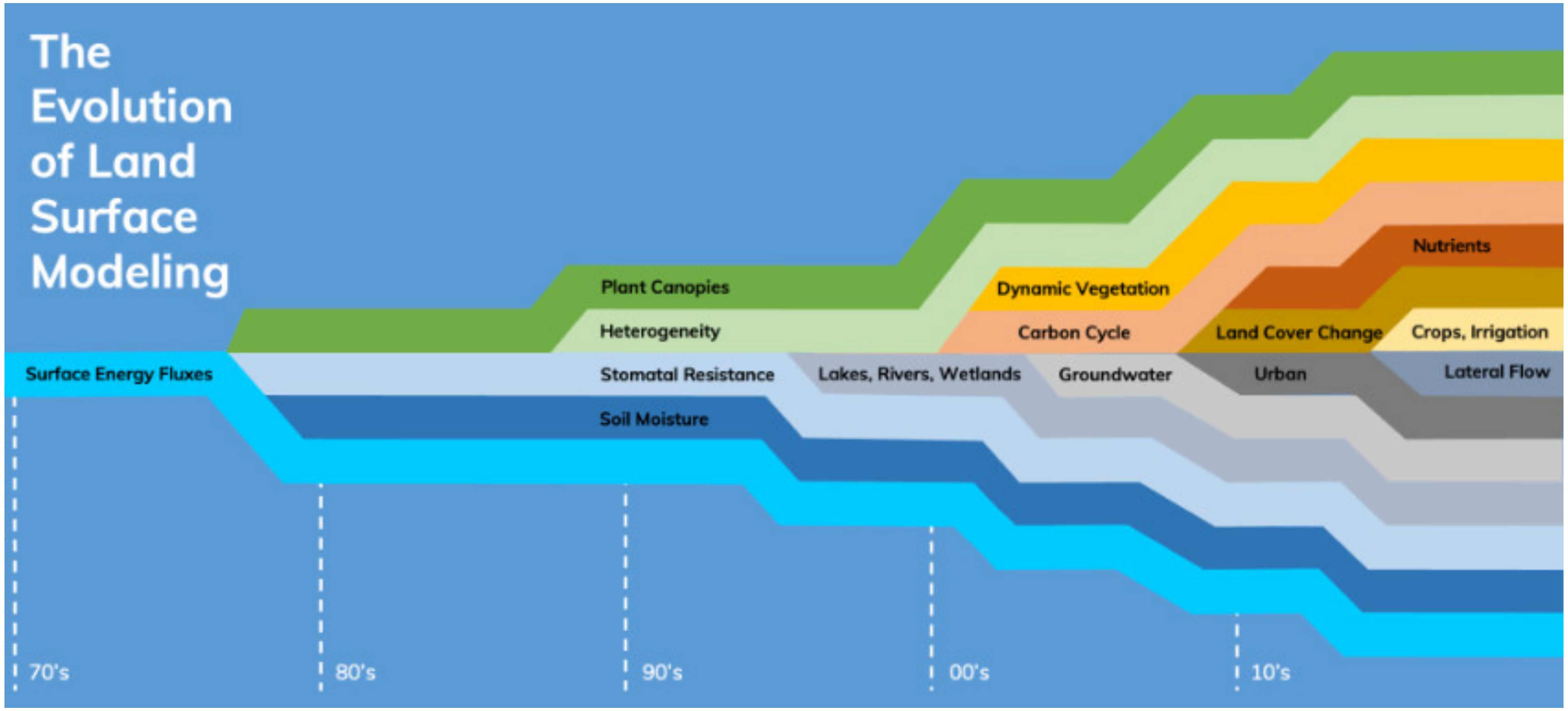


Figure by Rosie A. Fisher & Charles D. Koven in Perspectives on the Future of Land Surface Models and the Challenges of Representing Complex Terrestrial Systems (doi.org/10.1029/2018MS001453)

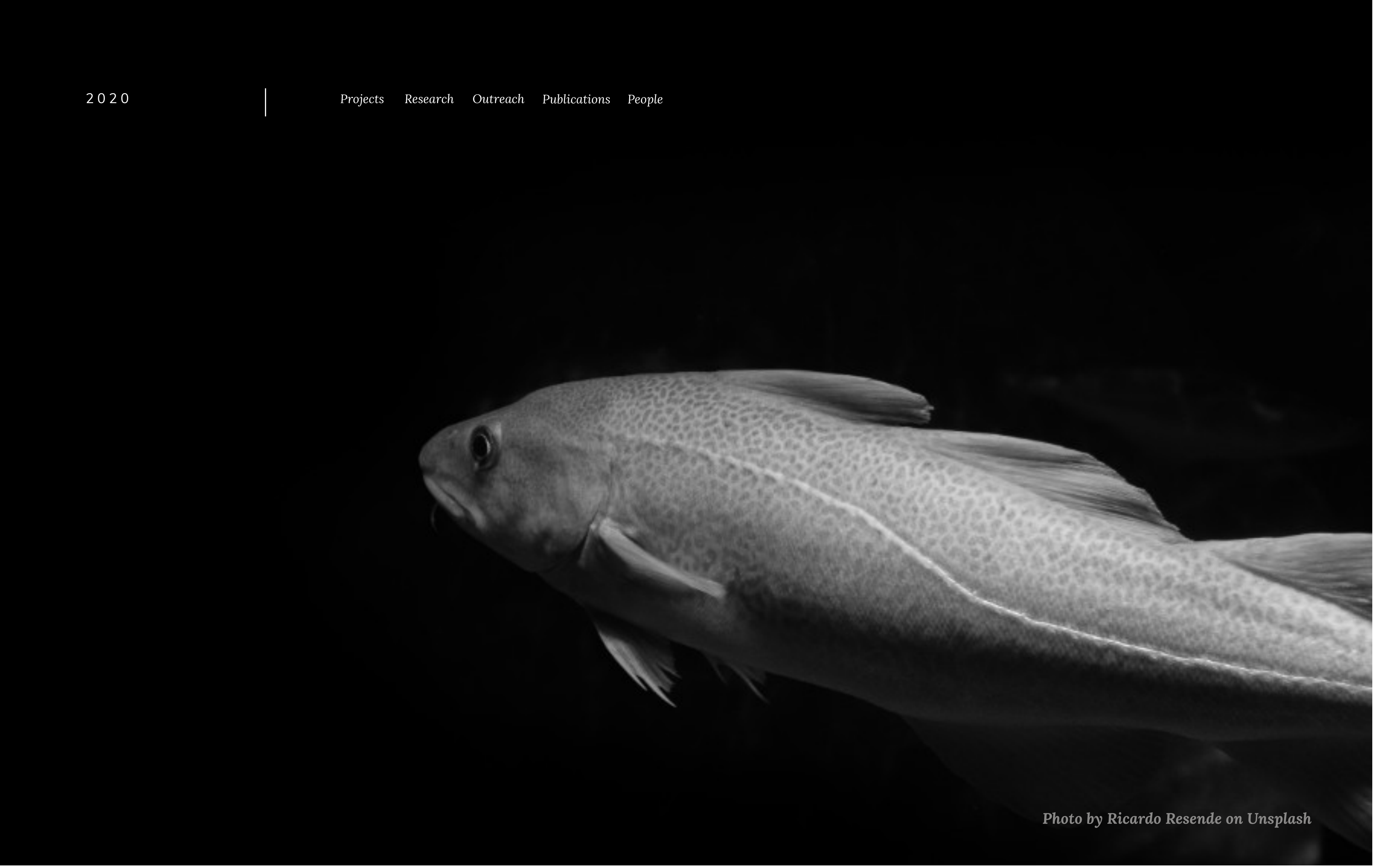


Photo by Ricardo Resende on Unsplash

HOW TERRESTRIAL CLIMATE CHANGE AFFECTS MARINE ECOLOGY

Tom Andersen
Department of Biosciences

With climate warming, a widespread expectation is that events in spring, like flowering, bird migrations, and insect bursts, will occur earlier because of higher temperature. However, in Norwegian coastal waters, a gradual delay in North-Atlantic cod spawning time by 40 days occurred between 1870 and 1980, after which the trend reversed. Cod spawning is expected to be linked food availability to the cod larvae, which again is linked to the phenology of the seasonal plankton cycle. The spring bloom of phytoplankton triggers this annual cycle. Sverdrup's critical depth is a classical explanation for the onset of the spring bloom: positive net phytoplankton growth is only possible when the critical depth exceeds the mixing depth of the surface layer. The critical depth is dependent on many factors, some related to celestial mechanics such as day length and solar elevation angle, and some to the optical properties of the water column. The light attenuation caused by colored dissolved organic matter (CDOM) is the main contribution to the latter. CDOM in coastal waters is typically exported from land. For the Norwegian coastal current, CDOM is contributed both from the Baltic Sea and by runoff from the Norwegian mainland.

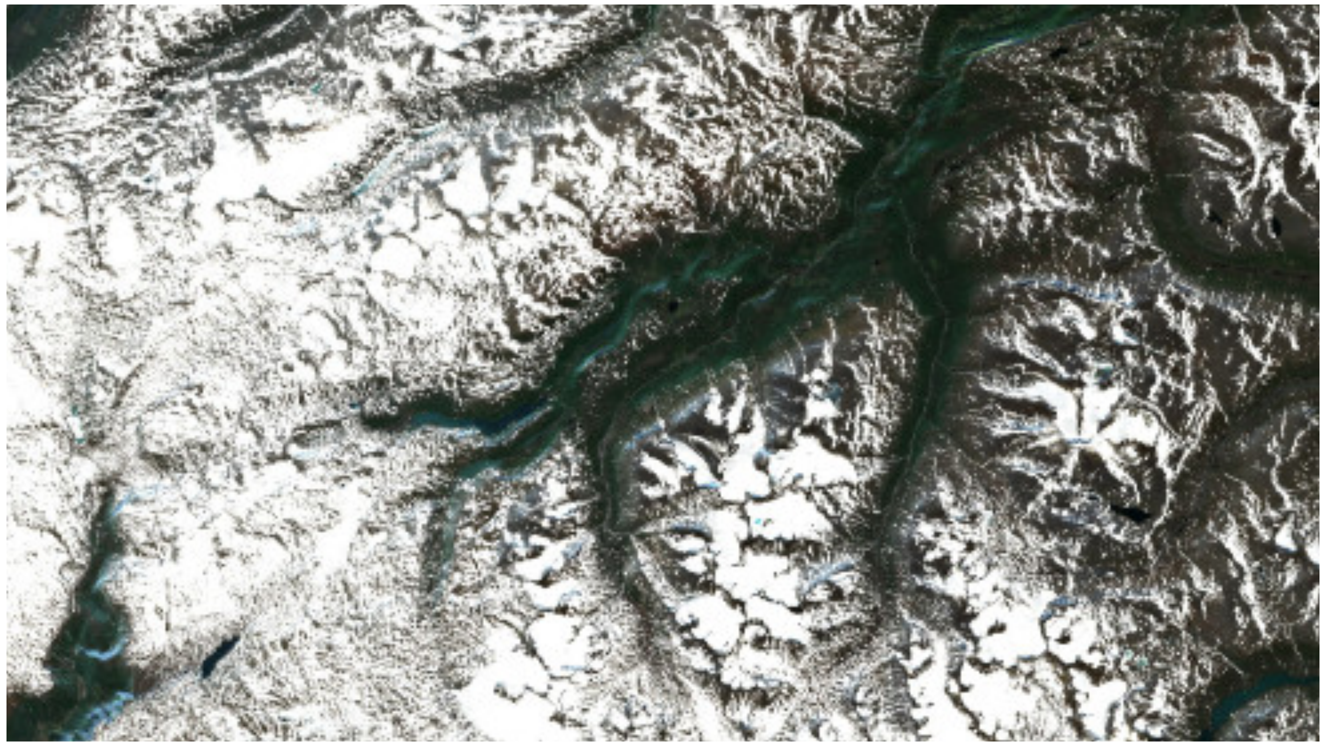
Several CBA researchers participate in a project led by Anders F. Opdal from the University of Bergen to investigate possible chains of events leading to the observed changes in cod spawning time. There are very few contiguous time series of relevant environmental factors covering the time span from 1870 to 2020. We therefore need to merge information from several sources, all with their strengths and weaknesses, such as model hindcasts of terrestrial CDOM exports, proxies from sedimentary archives, and time series with shorter coverage. One particularly promising proxy is stable carbon isotopes in organic matter from dated sediment cores. Since terrestrial organic matter will be more deplete in the ^{13}C isotope than carbon fixed by aquatic plants, we think we see a signal reflecting an increased load of terrestrial organic matter to the Oslofjord-Skagerrak region in the last hundred years. For time series of water transparency (Secchi disk reading) from the last 50-70 years in the same region, we try to disentangle effects of changes in phytoplankton biomass due to coastal eutrophication from changes in terrestrial CDOM exports. We also work with researchers in Finland to investigate changes in optical properties and spring bloom timing in the Baltic Sea, since this is the source of around half of the freshwater in the Norwegian coastal current.

FENNOSCANDIAN SNOW COVER PHENOLOGY FROM SPACE AND CLIMATE MODELS

Yeliz A. Yılmaz
Department of Geosciences

The snow cover is an essential part of the climate system in cold regions through its effects on land surface processes influencing the terrestrial water, energy, and carbon budget. Climate scientists use several tools in order to better understand the climate system at the local, regional, and global scales. Among these, Earth System Models (ESMs) are widely employed to simulate complex processes and make future climate projections. Our ability to improve the representation of these processes in the ESMs and to reduce the uncertainty in the climate projections leans heavily on the accuracy and representativeness of the observational data sets used for model evaluation. Having independent data sources for benchmarking is therefore vital for improving the ESMs.

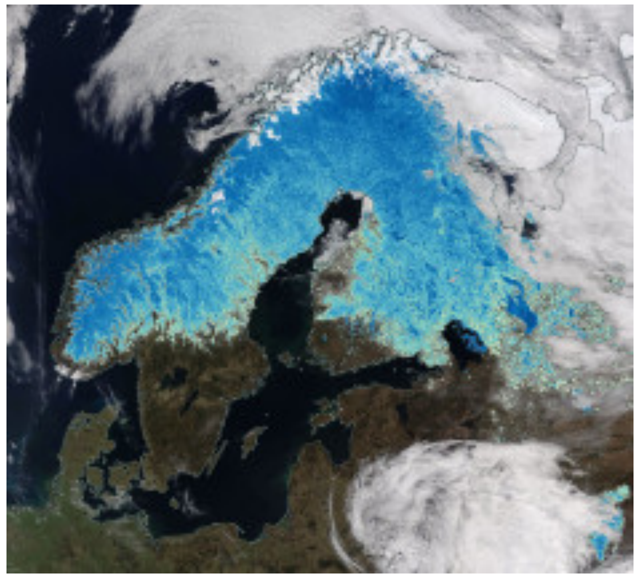
Earth observations from satellites have a big potential for climate research given that some of the missions provide multi-decadal observations for essential climate variables. In our work, we are currently exploiting the available satellite-based estimates of snow-covered area from different satellite sensors over the Scandinavian region. One of our aims is to produce representative snow cover maps over this region primarily for multidisciplinary research in both the LATICE and EMERALD projects. Additionally, the processed satellite-based snow products will be shared with the wider scientific community under the FAIR principles (Findable, Accessible, Interoperable, and Reusable).



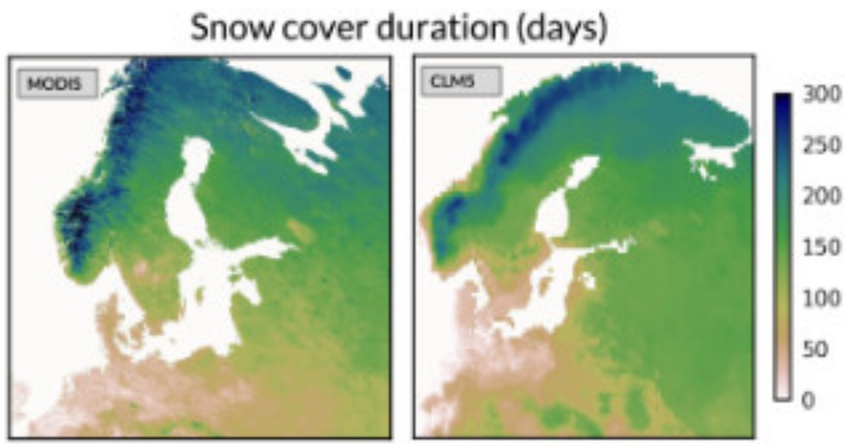
Sentinel-2 true color image over Jotunheimen sensed on 24.06.2020 (Credit: European Union, contains modified Copernicus Sentinel data 2020, processed with SentinelHub EO Browser)

Having representative snow cover maps enables us to better evaluate the terrestrial component of the Norwegian Earth System Model (NorESM), namely the Community Land Model (CLM5). With a focus on snow processes, we are conducting an analysis using satellite-based estimates of snow-covered area (MODIS, Sentinel-2, and Landsat 8), snow simulations from a land surface model (CLM5), and snow variables from several climate reanalyses (ERA5, ERA5-Land, MERRA-2, and GLDAS). We are investigating the trends in the snow cover phenology, which we characterize primarily using snow cover duration, first and last days of the snow cover, and consecutive snow cover days for each snow season over the last two decades. This contribution is an example of how the ESM community can improve model evaluation efforts in high latitude regions using the emerging long-term satellite climate data record.

Automatic camera image at the Iskoras flux site on 29.03.2019 at 16:29 (Credit: Norbert Pirk)



Snow cover index over Fennoscandia from MODIS-Terra on 15.04.2019 (Credit: NASA Worldview)



Snow cover days from MODIS and CLM5 (Credit: Yeliz A. Yılmaz)

This ongoing study is supported by the LATICE (Land-ATmosphere Interactions in Cold Environments) strategic research initiative funded by the Faculty of Mathematics and Natural Sciences at the University of Oslo, and the project EMERALD (294948) funded by the Research Council of Norway.

TIPPING POINTS

Dag O. Hessen
Department of Biosciences

The concept of tipping points became central to many of the CBA activities in 2020, and was set on the agenda by prof. Tim Lenton (in the scientific advisory board) in the annual CBA-talk in fall 2019. Also, the annual CBA-lecture of 2020 was devoted to this topic, and held in October by one the “forefathers” of the concept, prof. Marten Scheffer - also a member of the CBA scientific board

A ‘tipping point’ occurs when a small change in forcing triggers a large response from a system, qualitatively changing its future state. Several ‘tipping elements’ have been identified in the Earth’s climate system that may pass a tipping point due to climate change this century. For example, Steffen et al. (2018) explore the question: “Is there a planetary threshold in the trajectory of the Earth System that, if crossed, could prevent stabilization in a range of intermediate temperature rises?” They highlight the self-reinforcing feedbacks that could push the Earth System on to a “Hothouse Earth” trajectory, and focus on biophysical feedbacks such as permafrost thawing, weakening of carbon sinks, Amazon and Boreal forest dieback, and decreased C-sequestration in the oceans.

The concept may however also be used about social, normative, economic or technological tipping point. Scheffer has in his previous books explored societal tipping points, and his 2020-lecture was entitled “Ancient civilizations transformed when they reached a tipping point. Are we on the same track?» Some may be familiar with Malcolm Gladwells famous book from 2000 “The Tipping Point: How Little Things Can Make a Big Difference».

The major question today is how we can use insights in risks (and fear of) tipping points in nature and climate to motivate societal tipping points. Cai et al. (2016) explore causal interactions among tipping points and their implications for society, as measured by an economic indicator of the social cost of carbon. They find that the costs increase dramatically, sometimes quite abruptly. They further conclude that the possibility of multiple interacting tipping points causing irreversible economic damage should be provoking strong mitigation action. Similarly, Steffen et al. (2018) argue that avoiding dangerous feedbacks and climatic tipping points “requires that humans take deliberate, integral, and adaptive steps to reduce dangerous impacts on the Earth System, effectively monitoring and changing behavior to form feedback loops that stabilize this intermediate state.” Along the same lines, Lenton et al. (2019) argue that “... the consideration of tipping points helps to define that we are in a climate emergency and strengthens this year’s chorus of calls for urgent climate action - from schoolchildren to scientists, cities and countries.”

These feedbacks and tipping point risk are central to many of the CBA-activities, notably related to sudden climate changes. CBA is also involved in an application for an SFF (Center of Excellence) on feedbacks and sudden change in high latitude climate systems. In was also the title of the awarded and well recognized book “Verden på vippepunktet” (The world at the Tipping Point) authored by CBA-leader Dag Hessen.

2020 will enter history as the year of Covid-19. This has more than ever accentuated the feeling of a world at the tipping point, and with the rising awareness of the risks we are facing, the rise new technologies and not the least a growing understanding of need for economic and societal change, there are possibilities that the current situation may push the planet in the right direction.

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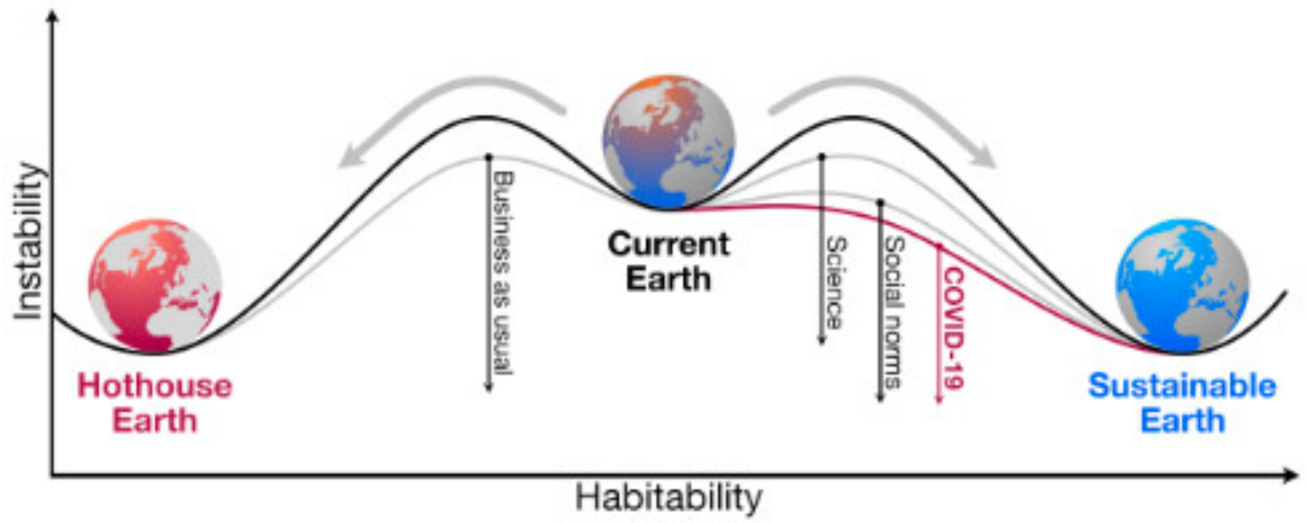


LAND-ATMOSPHERE EXCHANGE

Norbert Pirk
Department of Geosciences

In March 2019, the groups of Sebastian Westermann and Hanna Lee (Norce) established measurements of the land-atmosphere exchange of energy, CO_2 and CH_4 at the Iškoras palsa mire in Finnmark, using the mobile flux tower of the LATICE initiative. Its instruments are powered by an off-grid power supply and use the eddy covariance technique to continuously estimate the surface fluxes. The preliminary analysis shows spatial differences in carbon cycling between the palsa-dominated areas and the adjacent fen, which future modelling studies can be validated against.

Photo by Norbert Pirk.

ORGANIC POLLUTANTS IN TROPICAL CLIMATES

Maja Nipen
Department of Chemistry

In my PhD project, I am studying a group of chemicals known as persistent organic pollutants (POPs) which are used in a range of consumer products like plastics, building materials and electronics. Once these pollutants are released to the environment, their unique properties give them the potential to distribute between air, soil, water, sediment, and organisms, and they can travel globally as a passenger on wind and ocean currents. They can also travel globally with human assistance, embedded in traded products and waste. How these distribution processes play out depend on a range of environmental and human factors. Most research on POPs have been conducted in temperate or arctic areas, but little is known about their presence and environmental behaviour in tropical regions. Issues regarding waste handling, and limited capacity to enforce environmental regulation could indicate different sources of POPs in these regions, while elevated temperature and different soil properties could indicate differences in environmental behaviour.

Soil sampling for POP analysis (Photo by Maja Nipen)

To gain a better understanding of this, we have collected samples from air and soil from a range of urban and rural locations in Tanzania, which we have analysed for some POPs which are currently in use. The results from our study show that the currently used POPs are present in Tanzanian soil and air in high levels, even if these chemicals were never produced or used on the continent. The spatial trends show that there are differences in sources for the different POPs, where some appear to relate to electronic waste, while some are found wherever there is human activity.

In addition to soil and air samples, we have collected a sediment core in Tanzania which, when sliced and dated, show how the levels of POPs have changed in the local environment over time, and how the time trends differ for currently used POPs and historically used POPs. The sediment core data show that POPs have been present in the Tanzanian environment for some time, however, the levels of most of the POPs we looked at are increasing, and some at an exponential rate. This is not just a concern for the local population and environment, but also for the rest of us, given the global nature of these pollutants.

LAKES, MICROBES & DOC

Lina Allesson
Department of Biosciences

Over the past few decades, lakes have been undergoing a shift in water colour from rather clear to brown as a consequence of increased input of coloured dissolved organic carbon (DOC) from the terrestrial surroundings. This increase in DOC loadings can partly be explained by climate change. Higher temperatures yields enhanced biomass production in the catchment and together with intensified precipitation and run-off, more DOC enters the lakes.

Enhanced concentrations of coloured DOC, affects the CO_2 concentrations in lakes. CO_2 production increases when bacterioplankton consume the DOC and respire CO_2 and when the coloured DOC absorbs sunlight and photochemical processes converts it to CO_2. Sunlight absorption by DOC also shades the phytoplankton and hinders photosynthetic CO_2 uptake. Lakes with high concentrations of DOC therefore often act as net sources of CO_2 to the atmosphere.

In a study published in Limnology and Oceanography, we studied the CO_2 production in 70 lakes along a wide gradient in DOC concentrations. From physical, chemical and biological variables, we estimated microbial as well as photochemical CO_2 production. We were especially interested in whether the amount of photochemical CO_2 production in lakes depended on the DOC concentration.

Microbial CO_2 production was strongly dependent on DOC concentrations with more production in brown than in clear lakes. To the contrary, photochemical CO_2 production did not depend on colour but was similar in all lakes. The reason for this is that regardless of lake colour, all incoming solar radiation was absorbed in the water column. The largest difference between brown and clear lakes was at which depth the photochemical reactions took place. In the brownest lakes, close to all the photochemical CO_2 production happened at the surface, within only a couple of cm. In the clearest lakes, on the other hand, photochemical CO_2 production took place down to around five meters. This also implies that photosynthetic activity was restrained to the top few cm in brown lakes but could occur in a larger part of the clear lakes. CO_2 was mainly produced through respiration, and photochemical processes accounted for only a small fraction of lake CO_2 production. Increased sunlight absorption because of brownification therefore mainly affects lake CO_2 concentrations through inhibited photosynthesis and not through enhanced photochemical processes.

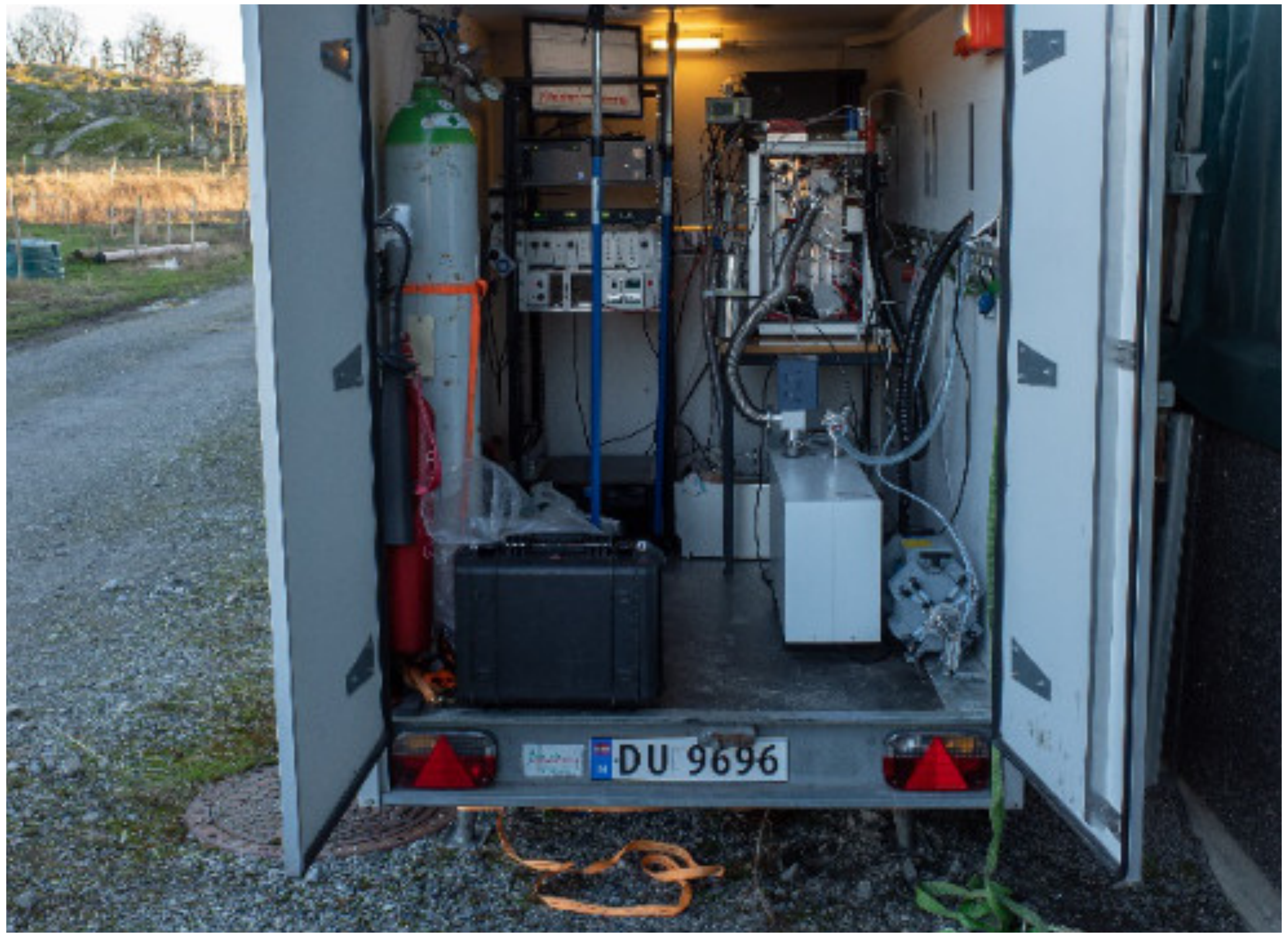
Lina Allesson and Jing Wei processing water samples in Finnmark (Photo by Nicolas Valiente Parra)

With the ongoing climate warming, we can expect DOC input to lakes to keep increasing and by that lakes becoming browner. As they do, CO_2 production in lakes will increase, mainly because of increased respiration, and most probably photosynthetic CO_2 consumption will decrease, turning more lakes net sources of CO_2 to the atmosphere.

Allesson, L., Koehler, B., Thrane, J.-E., Andersen, T. and Hessen, D.O. (2021), The role of photomineralization for CO2 emissions in boreal lakes along a gradient of dissolved organic matter. Limnol Oceanogr, 66: 158-170.

AMINE EMISSIONS FROM LIVESTOCK PRODUCTION

Alexander Håland
Department of Chemistry



Our fully automated mobile laboratory which is taking continuous air samples from the barn. Photo by A. Håland.

As a PhD-student in atmospheric chemistry, I investigate the emission, transport and fate of organic trace gases released into the atmosphere from various sources. The focus of my work is on amines, which are reduced nitrogen compounds that play an important role in atmospheric particle formation. Even with the most advanced chemical-analytical instrumentation it is difficult to measure amines in the air. One reason is that amine concentrations are typically very low, in the low parts-per-trillion (pmol/mol) range. Another reason is that amines are "sticky" molecules that are easily lost to surfaces in inlet tubes and inside the analyzer. Not much is thus known on sources and fate of atmospheric amines. The first part of my project was to contribute to the development and characterization of a novel mass spectrometer that is able to measure amines down to ppt-levels and with fast time response.

The barn at the Livestock Production Research Centre of the Norwegian University of Life Sciences (NMBU) where we are studying livestock emissions to the atmosphere. Photo: A. Håland

After many trials and errors in the laboratory, we finally succeeded in developing a novel instrument that can be taken to the field for studying emissions of amines from industry, agriculture and vegetation. Currently, we are conducting a study at the Livestock Production Research Centre of the Norwegian University of Life Sciences (NMBU) in Ås where we are measuring amines along with other important trace gases (methane, ammonia) that are emitted to the atmosphere. Agricultural production is indeed a major driver of the Earth system exceeding planetary boundaries, and while atmospheric research has been mostly focused on greenhouse gas emissions, much remains to be learned about agricultural emissions of other environmentally important gases.

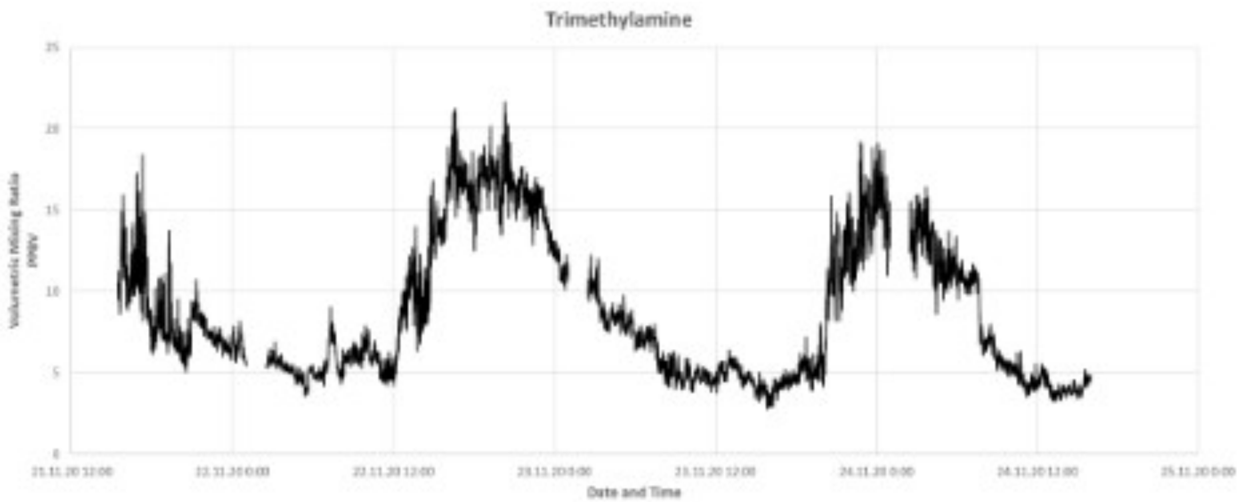


Figure 4: Time series of trimethylamine volume mixing ratios as measured inside the barn over the course of three days. The concentrations are three orders of magnitude higher than usually observed in the atmosphere, demonstrating that cattle are strong amine emitters. Data: A. Håland

CONTRASTS IN TERRESTRIAL TO MARINE TRANSFER OF ORGANIC MATTER AND NUTRIENTS BETWEEN TWO FJORD SYSTEMS

Sabrina Schultze
Department of Biosciences

The massive ongoing global environmental changes including climate change and transformation in land-use lead to alterations in distinct systems as well as to shifts in transfer dynamics of interconnected systems. One prominent example affecting the land-to-ocean connection is a documented increase in inputs of terrestrial derived dissolved organic matter for several northern coastal estuarine systems. The impact of these inputs depends on both its chemical composition ("quality") as well as its fate when entering more saline waters. As part of my PhD I have assess organic matter and nutrient dynamics along two different river-to-fjord systems, including the boreal Storelva-Sandnesfjord (a narrow southern Norwegian river-to-fjord system) and the subarctic Målselva-Målselvfjord (a broad subarctic Norwegian river-to-fjord system) in 2015/2016. The initial organic matter and nutrient concentrations in rivers and receiving marine waters and the type of fjord (narrow vs. broad, exchange with the open marine environment, degree of tidal influence) had a strong effects on water-chemistry patterns along the transect from land to sea and the freshwater-marine transfer in these systems. The narrow boreal system with little tidal influence and high riverine organic carbon and nutrient concentrations was structured mainly by the freshwater-marine salinity gradient, followed by season. In contrast, in the broad subarctic system, nutrient and organic carbon concentrations were not primarily structured by the salinity gradient, reflecting the lack of strong difference in concentrations between the river and deeper marine waters paired with stronger tidal mixing and exchange with the open marine system.Dissolved organic carbon (DOC) overall mixed conservatively in the narrow boreal system. POM of different sources, reflected in the δ13C values, also mixed conservatively. Total phosphorus also mixed conservatively in the narrow boreal system, while silicate was the only nutrient with conservative mixing patterns in the broad subarctic system. In both estuaries, the deep waters were decoupled from the surface waters, being very similar between the two systems and likely reflecting the compensatory deep inflow of Atlantic water. These results highlight the key role played by river chemistry and discharge, estuarine morphometry, and exchange with the open ocean in structuring transport, fate and potential impacts of terrestrial inputs of nutrients and organic matter in the coastal environment.

Målselvfjorden . Photo by Petr Brož on Wikipedia (CC BY-SA 3.0)

BROWNING WATER & BIODEGRADABILITY

Camille Crapart
Department of Chemistry

Freshwater is one of the most abundant resources of Norway. With more than 243 000 lakes and 70 000 m^3 available per inhabitant per year, Norway is the water-richest European country. Depending on their localisation, Norwegian lakes reflect the variety of the main climatic regions of Norway (artic, atlantic, alpine and boreal) and they also reflect the environmental changes of these regions. One example is the phenomenon called "browning", that boreal lakes (in south-eastern Norway) have been experiencing in the last decades. In these lakes, the water became browner and browner, due to an increasing quantity of organic matter in suspension. Organic matter is composed of dead organic compounds like proteins, lipids and carbohydrates, that are the bricks constituting all living organisms. It originates from plants and animals' secretions and decomposition and has a brown colour. Heterotrophic bacteria, at the basis of the food chain, feed on organic matter: this process is called biodegradation. An increasing concentration of organic matter is likely to impact the biodegradation processes. "To which extend?" This is the question I am trying to answer during my PhD.

From greening to browning

Several factors explain the increasing concentration of organic matter in lakes. On the one hand, boreal regions used to suffer from acid rains, that lowered the pH of surface water and reduced the solubility of organic matter. After European regulations on acid emissions, acid rains stopped, and organic matter remained in the water. On the other hand, the forests surrounding the lakes are becoming greener due to higher temperatures and longer growing seasons, but also less human harvesting and more available nutriments, such as nitrogen. When more tree and bushes grow on the watershed, more organic matter will be exported to the lakes when it rains, adding up to the organic matter produced in situ by algae and phytoplankton.

Why is organic matter so important?

Organic matter can have harmful impact on lake communities. First, organic matter can transport both pollutants and nutriments from the catchment to the lake. If it brings too much nutriments, eutrophication can happen: blue-green algae will over-develop and take over the ecosystem. If it brings too much pollutants, the lake can become unsuitable for life. Second, it absorbs the sunlight, creating a warm surface layer of water under which neither light nor heat will be available. This layer also contains more oxygen and nutriments. Consequently, algae (depending on sunlight to do photosynthesis), fishes and other living organisms will pack in there.

But organic matter is at the bottom of the food chain. The smallest molecules of organic matter (with a

Camille Marie Crapart sampling surface water from Kviteseidvatn, Telemark (Photo by Nicolas Valiente Parra)

diameter under 0,45 um), called "dissolved", are the main source of food for the heterotrophic bacterial communities in soils and lakes. Unlike photosynthetic plants, heterotrophic bacteria cannot use atmospheric CO_2 as a source of carbon to sustain their metabolism. They assimilate some ready-made organic compounds to build themselves and they oxidize some others to produce energy by respiration: they use O_2 to decompose organic compounds into CO_2 and H_2O, producing energy. This breaking down process controls the availability of energy and nutriments for the rest of the ecosystem, as well as the production of greenhouse gases. We already know that proportion of organic matter that bacteria can degrade depend on the kind of organic matter and its origin. But we know little on how fast they can degrade it, and which are the factor that will make the bacterial community go faster or slower.

"The impact of climate change on the biodegradability of organic matter in boreal lakes"

This is the goal of my PhD thesis: explain what influences the biodegradability of organic matter. Is it the characteristics of the organic matter (light, heavy, coloured)? Is it the nutrient status of the lakes: eutrophic (with a lot of nutriments), oligotrophic (clear water), dystrophic (with a lot of organic matter)? Is it the pH? In order to answer that question, I measured the evolution of oxygen concentration in 73 samples collected in 2019 in 73 boreal lakes. The rate of consumption of oxygen, or respiration rate, gives an indication on the metabolic activity of the bacteria, and therefore on the speed of consumption of organic matter. By analysing this data together with a large variety of parameters measured on the same samples, I will investigate these hypotheses and, hopefully, contribute to understand the bacterial processes in lakes in our changing environment.

CAUSES OF PLANT MORTALITY FROM EXTREME WINTER EVENTS

Model insights into desiccation processes during frost droughts

Marius Lambert
Department of Geosciences

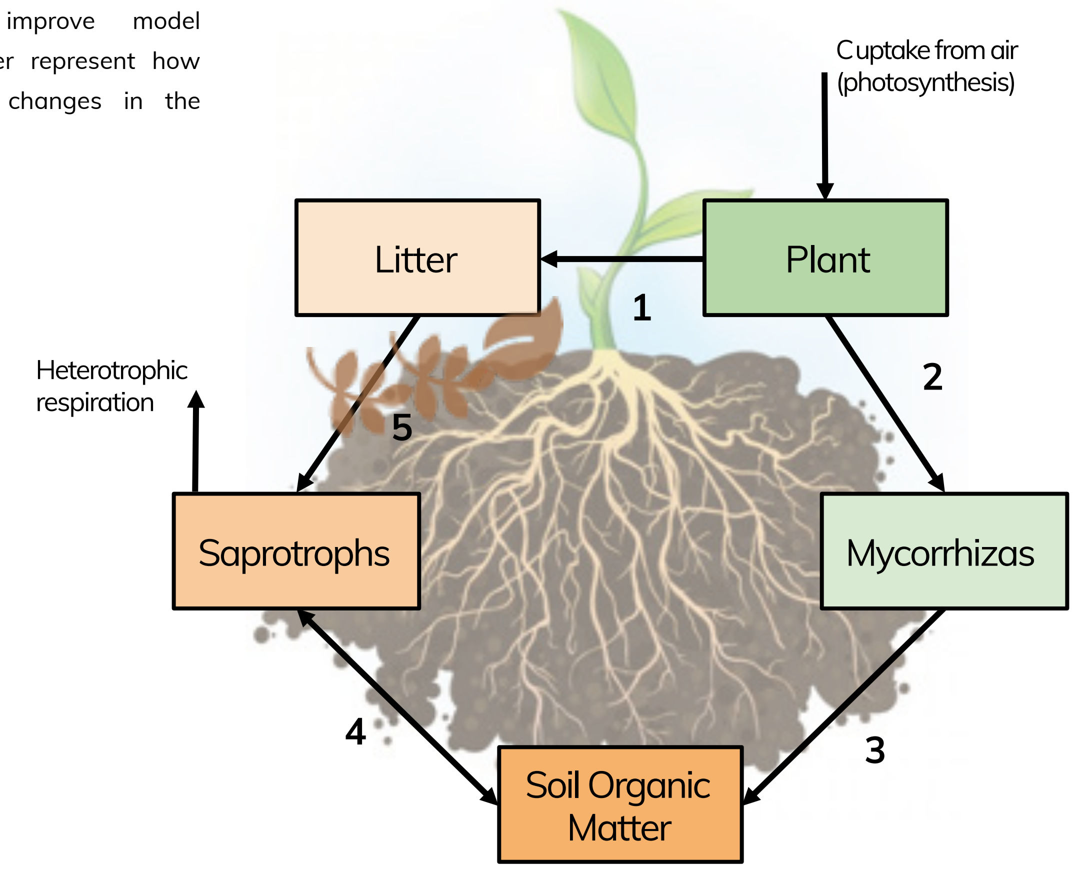
The Arctic has seen its vegetative cover flourish in the last decades. Plants grow bigger, progressively expand northwards and move upwards along mountain slopes. But as the overall living biomass goes up, significant areas across the Arctic showed a decrease in vegetation productivity in recent years. This phenomenon, called "Arctic browning" is driven by a growing number of wildfires, insect outbreaks and extreme weather events, all associated with climate change. Extreme events can initiate icing, loss of freeze tolerance, frost droughts and several other mechanisms inducing damage and ultimately death of tissues. Frost droughts, although poorly understood, are the reason of a considerable proportion of observed damage. They strike when the association of freezing soils due to the lack of snow and high irradiance reach critical values preventing plants from replacing transpired water. Until recently, regional and global models couldn't simulate frost droughts. Terrestrial biosphere and other large scale models tended to represent plant water transport as one single resistance term, or ignore plant hydraulics completely. Nowadays, most of them incorporate much more detailed plant water modules, based on tissue (root, stem, leaf) level traits. For my PhD I am using the Fates-hydro model driven by high resolution COSMO-REA6 to evaluate how frost droughts impact vegetation mortality in northern Norwegian landscapes. We already established a clear link between snow depth and drought intensity. Indeed, the snow pack is crucial to insulate the soil from cold atmospheric temperatures during winter. A shallow snow layer will result in colder soils and hence less available liquid water for plants. We found out that root water exudation (water leaving the roots) at low soil water potentials rather than transpiration at high vapor pressure deficit explained tissue desiccation during shallow snow covered winters. We are now expanding our research to the whole northern Norwegian area to see if this is still observed at larger scales, and to identify if some regions have been strongly hit by droughts over the period 2012-2020.

SOIL CARBON MODELING

Elin Cecilie Ristorp Aas
Department of Geosciences

In my PhD project, the aim is to develop a model for soil carbon and nitrogen dynamics, with a special focus on microbial activity. We want to better understand the role of decomposing saprotrophs and symbiotic mycorrhizal fungi during carbon and nutrient cycling below ground.
Through interdisciplinary collaboration we search to improve model parameters to better represent how microbes react to changes in the environment.

Our long term goal is to integrate this model into an Earth System Model, to study the possible effects climate change on microbial activity, and thereby on soil-atmosphere carbon exchange.



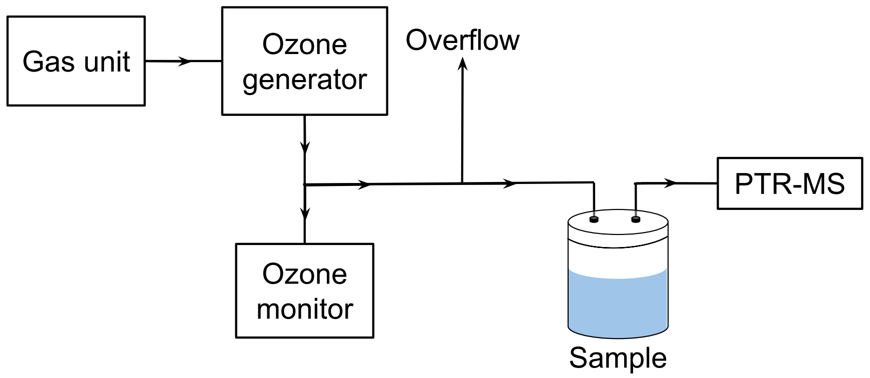
Overview over soil carbon processes. 1. Plant material turns into litter, 2. mycorrhizal fungi receives C from the plant in return for N, 3. mycorrhizal necromass turns into SOM, and 4. Saprotrophs decomposes the SOM.

VOLATILE ORGANIC COMPOUNDS FROM LAKE WATER DURING EXPOSURE TO UV RADIATION AND OZONE

Hanne Ødegaard Notø
Department of Chemistry

The uppermost layer of water in lakes is the section where a lot of interesting chemistry happens. This section of the water is the only one in direct contact with the atmosphere, and it is the most exposed to UV radiation from the sun. Photooxidation of the organic carbon in the surface layer is an important mechanism in the degradation of plants and organisms, and volatile organic compounds (VOCs) are often formed in the process and lost to the atmosphere. Studying the photooxidation and ozonolysis processes that happen in the water-air interface can improve our understanding of how carbon is lost to the atmosphere, as well as the quantity lost. In a study of 10 lakes in the Oslo area, the aim was to characterize and quantify the VOCs emitted from the lake water during exposure to ultraviolet (UV) radiation and ozone using proton-transfer reaction mass spectrometry (PTR-MS). The PTR-MS allows for rapid on-line measurements. Three different exposures were executed on all 10 lake samples: UV radiation, UV radiation + ozone exposure, and ozone exposure. The UV radiation had intensities and wavelengths similar to that of bright sunlight in the range 290-800 nm. The ozone concentration was kept at 40 ppb, which is in the range of normal tropospheric ozone levels.

Most of the VOCs observed were formed during UV exposure, which indicates that sunlight may be one of the main drivers of organic carbon emissions from lakes. A large fraction of the compounds observed were saturated and unsaturated aldehydes, which can be formed during the photooxidation or ozonolysis of the humic matter found in lakes. Heptadecene was emitted from the lakes during UV exposure only, and this compound can be produced by cyanobacteria as a stress-response to UV radiation. Surface waters make up a small percentage of the Earth's surface, but some of the chemical processes observed in this study may also occur in the oceans, which is of higher global significance.

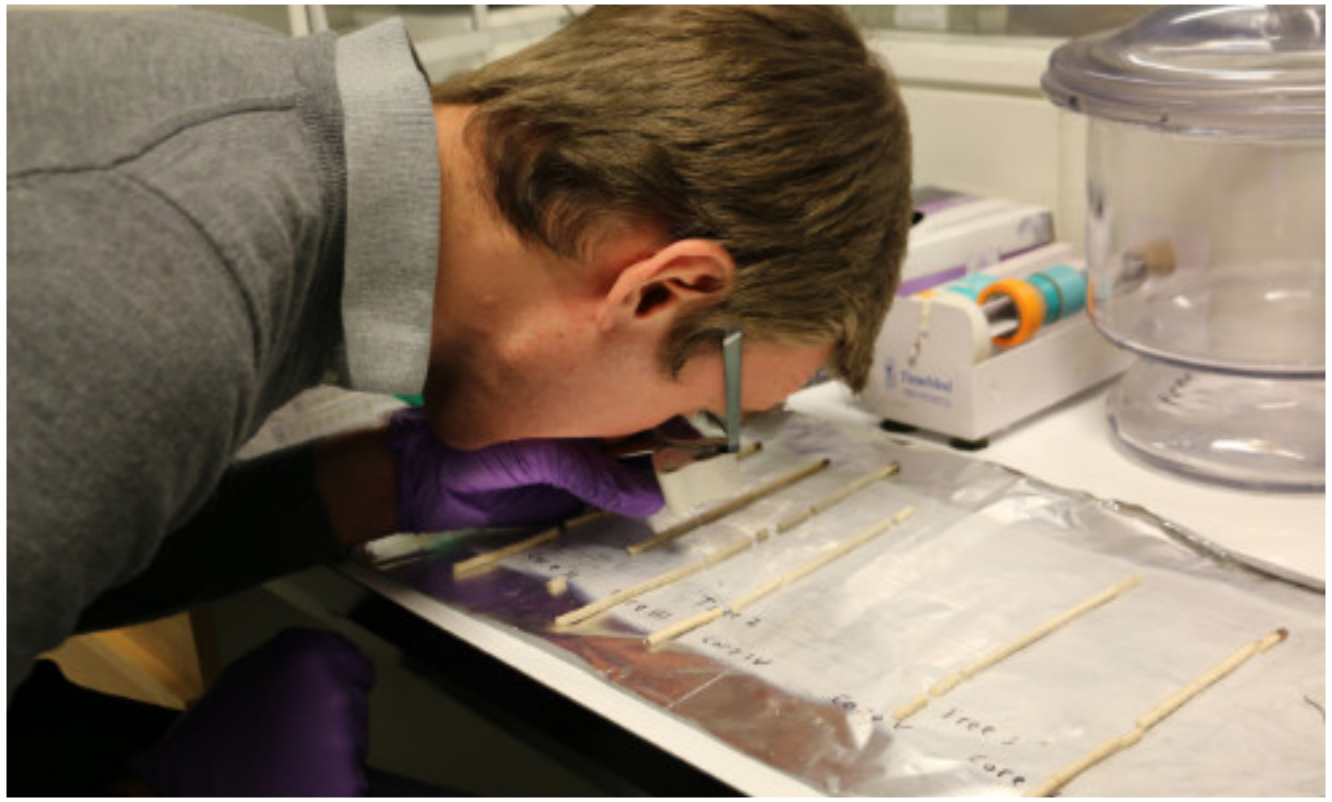


Schematic view of the experimental set-up. A gas unit free of VOCs was coupled to an ozone generator which can be turned on and off. The gas flow then splits and flows into the ozone monitor as well as into the sample vessel. The flow in the sample vessel carries any gas phase VOCs produced into the PTR-MS for detection.

CLIPT LAB 2020

William Hagopian & Anne Hope Jahren
Department of Geosciences

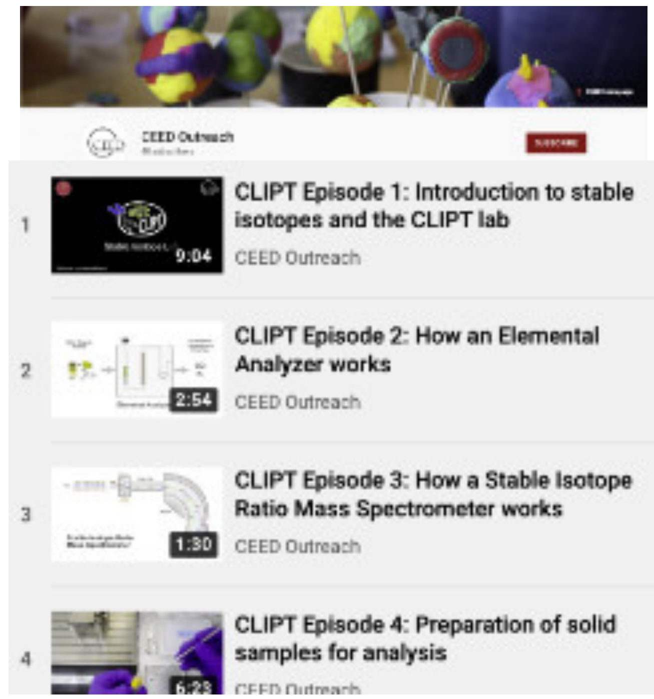
The CLIPT lab is a stable isotope laboratory collaborating with researchers from across the university in a diverse array of fields. While this past year has been challenging due to COVID-19, the CLIPT lab has remained optimistic and committed to providing support for CBA researchers by adapting to the modified work environment and developing online resources. The CLIPT lab video series launched in September and currently provides researchers and students with remote access to important information about the CLIPT lab, preparation protocols, and educational videos on stable isotope analysis.
After the unexpected shutdown in March, the CLIPT lab resumed sample analysis, prioritizing student projects and research activities that were under time constraints. By closely coordinating with our users, we have been able to continue with consultations and analyses throughout the remainder of 2020. This past year we have supported 24 different projects, and contributed to 3 published papers, 4 manuscripts in review, and 6 completed thesis projects. We look forward to supporting the exciting CBA projects coming up in 2021 and are exploring the possibility to expand our analytical capabilities to include enriched stable isotope analyses, which would open up many CBA opportunities in carbon and nitrogen cycling research.

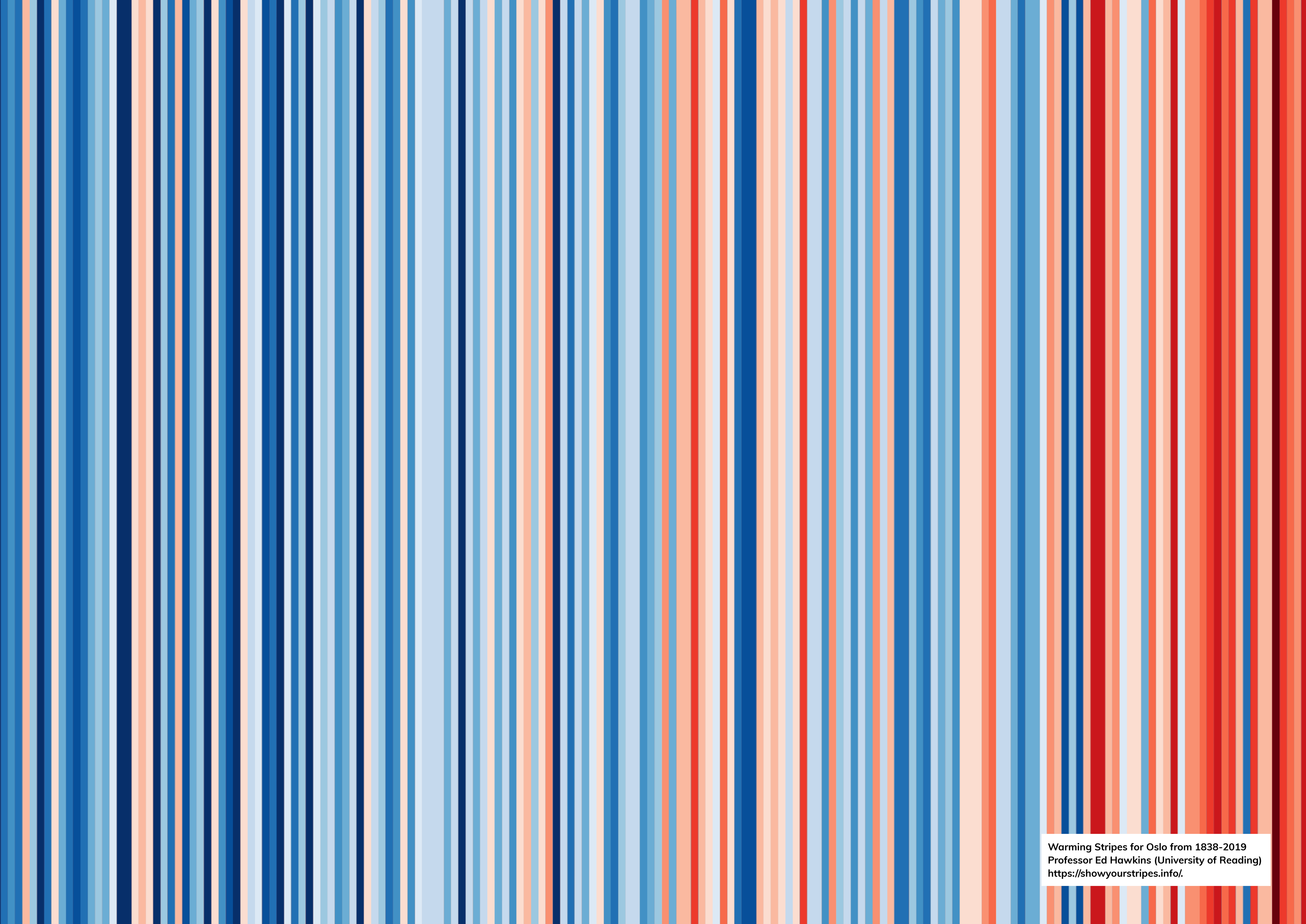


Josh Bostic inspecting wood with hand lens (photographer Gunhild M. Haugnes/UiO)

Examples of substrates the CLIPT lab has analyzed this year (clockwise from top left): geologic sedimentary layers, fruit fly embryo, modern soil, lake sediments, killer whale, arabidopsis, human blood, Viking age wood. Photo credits: William Hagopian (all except fruit fly embryo and killer whale)

COVID-safe info for CLIPT lab users: A new video series on Youtube!





Warming Stripes for Oslo from 1838-2019
Professor Ed Hawkins (University of Reading)
https://showyourstripes.info/.

EDUCATION

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.

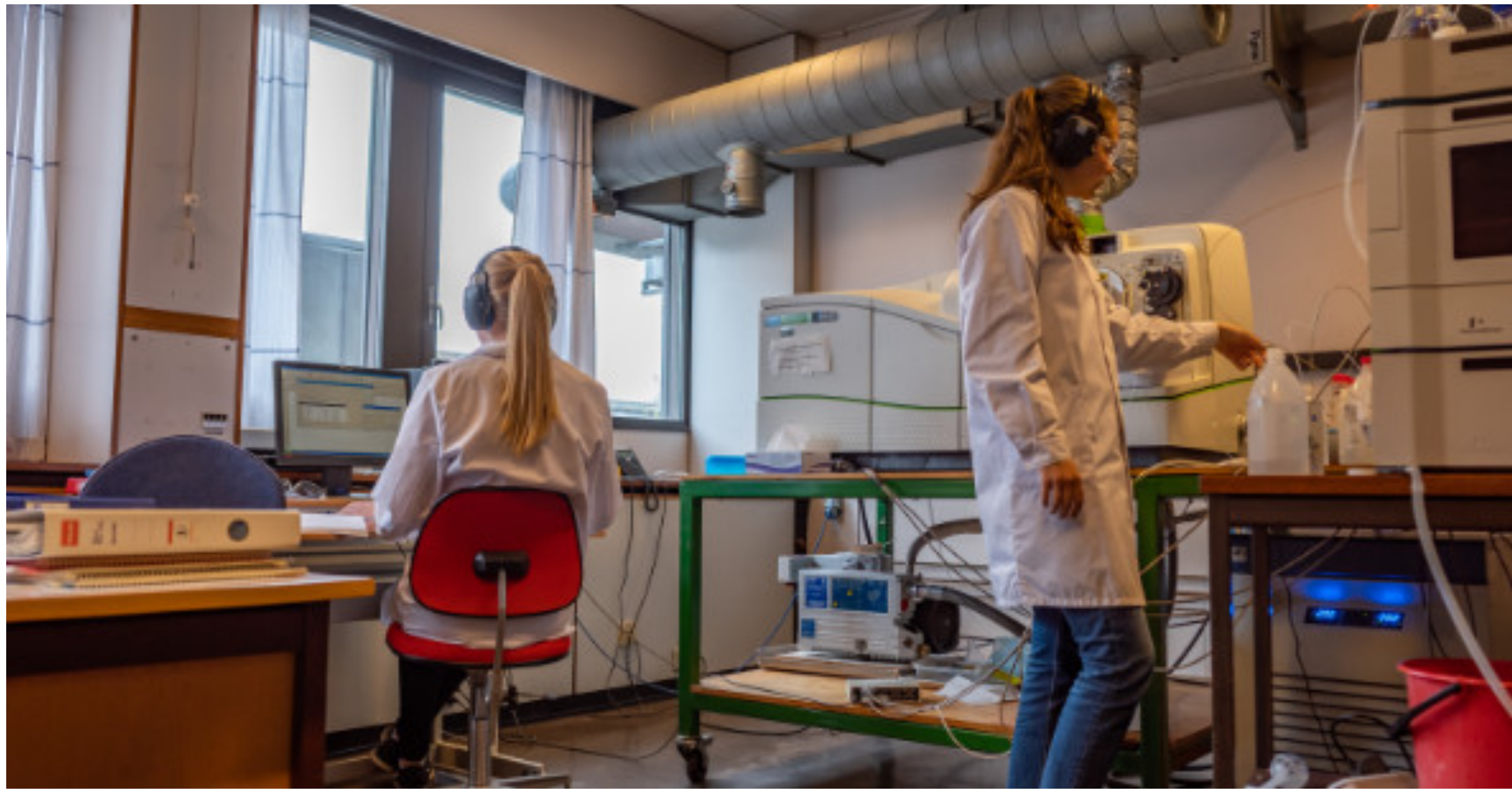
GEO4161 Contaminants in the geoenvironment
Contaminants in soils and ground water pose a threat to our society and the limited land and water resources. The course covers types of contaminants, both organic and inorganic; physical/ chemical distribution among phases/media; biogeochemical processes in soils and groundwater; transport of contaminants; risk assessment and natural attenuation.

KJM3070 / BIOS3070 sampling at Kolbotntjernet, Oslo

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 consequences 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.

KJM5700 Environmental Chemistry II
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 controlling 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 processes 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.



ICP-MS laboratory at the Dpartment of Chemistry

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.

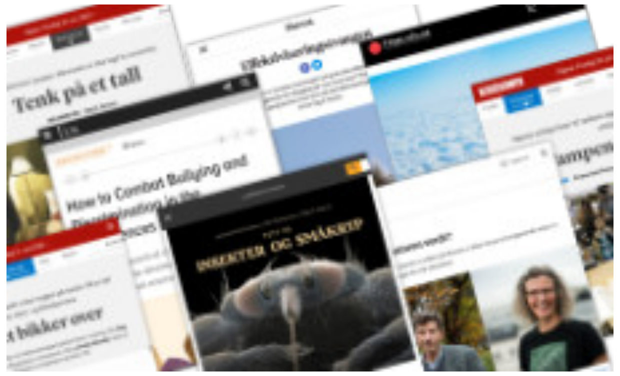
GEO4904
The course deals with the basic processes that govern the composition of chemically active species in the atmosphere (gases and aerosols). This is crucial in understanding trends in short-lived greenhouse gases, aerosols, ozone depletion in the stratosphere, acidification and regional air pollution. The course gives an introduction to modelling of atmospheric chemistry in e.g. Earth System Models.

OUTREACH

CBA's researchers engage with the public through books, newspaper articles, interviews, and public talks.

Newspaper pieces

- Andrea L. Popp, Caitlyn A. Hall, and Yeliz A. Yılmaz How to Combat Bullying and Discrimination in the Geosciences 24.11.20. https://eos.org/opinions/how-to-combat-bullying-and-discrimination-in-the-geosciences
- Anders Bryn, Dag Hessen, og Frode Stordal. Før det bikker over. Klassekampen. 11.05.20
- Frans-Jan W. Parmentier. Tampen Brenner, Column in Klassekampen, 24.07.2020. Parmentier is a regular columnist in Klassekampen, the Naturligvis column
- Heleen de Wit (NIVA og CBA) og Marianne Bechmann (NIVA). Det grønne skiftet kan gi oss grønt vann. Aftenposten Viten. 15.12.20.
- Dag O. Hessen. Effektiviseringstvangen, Pan-Harvest Magazine 18.12.20
- Dag O. Hessen. Tenk på et tall. Klassekampen. 18.11.20
- Dag O. Hessen.Klima – hvor står vi og hvor går vi? Fagbladet, 15.10.20
- Dag O. Hessen. 2020 skulle bli klimahandlingens år. Så kom korona. Aftenposten 11.05.20
- Dag O. Hessen. Uthuling, underminering og uforstand. Morgenbladet 29.05.20. https://morgenbladet.no/ideer/2020/05/uthuling-underminering-og-uforstand
- Dag O. Hessen. Klima, korona og kriser. Harvest Magazine, 13.03.20.
- Dag O. Hessen. Drømmen om «frikobling». Harvest, 09.03.20. https://www.harvestmagazine.no/artikkel/drommen-om-frikobling
- Dag O. Hessen. Innlegg: Dette må til om klima og kapital skal bli en god allianse. 27.02.2020. Dagens Næringsliv
- Dag O. Hessen, Anne Sverdrup-Thygeson. Hva er naturen verdt? NRK Ytring. 24.09.20.



Books

- Hessen, D.O. Verden på vippepunktet. Res Publica
- Wiik-Nielsen, Mathismoen, O., Hessen, D.O, J. Tett på insekter og andre småkryp. Fontini/Cappelen Damm
- Hope Jahren. The Story of more. Vintage.

Interviews

- Can We Really Combat Climate Change by Consuming Less? Maybe. Smithsonian Magazine. 02.03.20. Interview with Anne Hope Jahren
- Nei til klimagasser er ja til framtida, Titan, 31.03.2020. Interview, Dag .O. Hessen
- 5 interviews for broadcasting related to climate and writing with Dag O. Hessen
- Slik vil miljøkjemikerne bidra til en bedre verden. Titan 15.9.2020 Rolf D. Vogt Torgersen, Eivind.
- Mol - en måleenhet til glede og frustrasjon. Titan 23.10.2020 Interview with Rolf D. Vogt
- Mixed-phase clouds slow down global warming, but only up to a certain point. Titan, 26.10.20. Interview with Trude Storelvmo
- Ny labteknologi skal redde fisk fra pest og parasitter, Titan. 29.10.20. Interview with Alexander Eiler
- Nytt miljøproblem i Norge: Klimaendringer gjør havet mørkere. NRK.no. 31.10.20. Interview with Dag .O. Hessen
- Vaksinerer med vitenskap. Dagsavisen 28.11. Interview, Dag .O. Hessen
- Menneskenes ting veier mer nå mer enn alt levende på jorda. 09.12.20. Interview with Dag O. Hessen
- ARCTIC-BIODIVER project: a changing Arctic (in Spanish). Interview with Nicolas Valiente Parra for the Researchers around the World

Talks & Presentations

- Frans Jan Parmentier: talk on Arctic Ecosystems: The thin green line between the soil and the atmosphere . Geo Wednesday. Realfagsbiblioteket
- Dag O. Hessen Blå skog i natur- og klimakrisens tid – et fugleperspektiv på Blå skog-uka
- Rolf David Vogt, & Camille Marie Crapart . Pressures governing dissolved natural organic matter. The Norwegian Environmental Chemistry Symposium 2020; 2020-09-14 - 2020-09-16 UiO
- Jørgensen, Susanne Jøntvedt; Nipen, Maja; Vogt, Rolf David. Spatial trends of heavy metals in soil from a tropic region. The Norwegian Environmental Chemistry Symposium 2020; 2020-09-14 - 2020-09-16 UiO
- Nipen, Maja; Bohlin-Nizzetto, Pernilla; Borgen, Anders; Borgå, Katrine; Jørgensen, Susanne Jøntvedt; Mmochi, Aviti John; Mwakalapa, Eliezer Brown; Schlabach, Martin; Vogt, Rolf David; Breivik, Knut. Spatial trends of chlorinated paraffins and dechloranes in soil and air from Tanzania. Norwegian Environmental Toxicology Symposium (NETS2020); 2020-11-04 - 2021-01-05 NILU UiO

The Story of More by Anne Hope Jahren

Verden på Vippepunktet by Dag O Hessen

SEMINARS @CBA

- Tipping points and possible effects of Covid-19. Talk by **Dag O. Hessen**. 18.6.20
- CBA annual meeting 6.-7.11.20 in Drøbak with talks from 27 CBA researchers. External talk from **Bjørn Samset**, CICERO: Climate change as of 2020: We know everything, and therefore not nearly enough
- Organic pollutants in air and soil in a tropical climate. Talk by **Maja Nipen**. 10.11.20
- The annual CBA lecture: Lost Attraction. How civilizations transform. Talk by **Maarten Scheffer**. 19.11.20
- Knowledge from fossils. Talk by **Lene Liebe Delsett**. 24.11.20
- The projects EMERALD (Terrestrial ecosystem–climate interactions of our EMERALD planet) and LATICE (Land-ATmosphere Interactions in Cold Environments). Talk by **Lena Marie Tallaksen**. 8.12.20

Camille Crapart (2nd from left) receiving the NECS poster prize.

AWARDS

- ***Nicolas Valiente Parra*** *- Best dissertation in Limnology for the period 2018-2019 from Iberian Association of Limnology*
- ***Trude Storelvmo*** *- University of Oslo's award for Young researchers for 2020*
- ***Camille Crapart*** *- Best poster prize at the The Norwegian Environmental Chemistry Symposium, NECS 2020*
- ***Dag O Hessen*** *- Brageprisen for beste sakprosa og Hedersprisen - ENG: Brageprisen for best non-fiction and the honorary award*

CBA PUBLICATIONS

Andersen, T., Hessen, D.O., Håll, J.P. et al. 2020. Congruence, but no cascade—Pelagic biodiversity across three trophic levels in Nordic lakes. Ecology and Evolution 10: 8153 – 8165, https://doi.org/10.1002/ece3.6514

Anderson, T.R, Raubenheimer, D., **Hessen, D.O** et al. 2020. Geometric stoichiometry: unifying concepts of animal nutrition to understand how protein-rich diets can be "too much of a good thing". Frontiers in Ecology and Evolution, doi: 10.3389/fevo.2020.00196

Antonsen, S. G., A. J. C. Bunkan, T. Mikoviny, C. J. Nielsen, Y. Stenstrøm, **A. Wisthaler**, E. Zardin. 2020. Atmospheric Chemistry of Methyl Isocyanide – an Experimental and Theoretical Study, J. Phys. Chem. A 124(32), 6562-6571, doi: 10.1021/acs.jpca.0c05127

Antonsen, S. G., A. J. C. Bunkan, T. Mikoviny, C. J. Nielsen, Y. Stenstrøm, **A. Wisthaler**, E. Zardin. 2020. Atmospheric chemistry of diazomethane - an experimental and theoretical study, Mol. Phys. 118(15), doi: 10.1080/00268976.2020.1718227.

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L.-E. Cassagnes, L. Zaira, A. Håland, D. Bell, L. Zhu, A. Bertrand, U. Baltensperger, I. El Haddad, **A. Wisthaler**, M. Geiser, J. Dommen, Online monitoring of volatile organic compounds emitted from human bronchial epithelial cells as markers for oxidative stress, J. Breath Res., doi: 10.1088/1752-7163/abc055, in press (2020)

Chadburn, S. E., Aalto, T., Aurela, M., Baldocchi, D., Biasi, C., Boike, J., Burke, E. J., Comyn-Platt, E., Dolman, A. J., Duran-Rojas, C., Fan, Y., Friborg, T., Gao, Y., Gedney, N., Göckede, M., Hayman, G. D., Holl, D., Hugelius, G., Kutzbach, L., Lee, H., Lohila, A., **Parmentier, F. J. W.**, Sachs, T., Shurpali, N. J. and **Westermann, S.**: Modeled microbial dynamics explain the apparent temperature-sensitivity of wetland methane emissions, Global Biogeochemical Cycles, e2020GB006678, doi:10.1029/2020GB006678, 2020.

J. Chen, D. Yin, Z. Zhao, A. P. Kaduwela, J. C. Avise, J. A. DaMassa, A. Beyersdorf, S. Burton, R. Ferrare, J. R. Herman, H. Kim, A. Neuman, J. B. Nowak, C. Parworth, A. Jo Scarino, **A. Wisthaler**, D. E. Young, Q. Zhang. 2020. Modeling Air Quality in the San Joaquin Valley of California during the 2013 DISCOVER-AQ Field Campaign, Atmos. Environ.: X 5, 1000067, doi: 10.1016/j.aeaoa.2020.100067.

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de Wit, H. A., A. Lepistö, H. Marttila, H. Wenng, M. Bechmann, G. Blicher-Mathiesen, K. Eklöf, M. N. Futter, P. Kortelainen, B. Kronvang, K. Kyllmar and J. Rakovic. 2020. Land-use dominates climate controls on nitrogen and phosphorus export from managed and natural Nordic headwater catchments. Hydrological Processes 34(25): 4831-4850.

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Fernandez, L., S. Peura, **A. Eiler**, A. M. Linz, K. D. McMahon and S. Bertilsson. 2020. Diazotroph Genomes and Their Seasonal Dynamics in a Stratified Humic Bog Lake. Frontiers in Microbiology 11(1500).

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S. Kim, R. Seco, D. Gu, D. Sanchez, D. Jeong, A. B. Guenther, Y.-R. Lee, J. E. Mak, L. Su, D. B. Kim, J. Ahn, J. Sullivan, T. Mcgee, R. Long, W. H. Brune, A. Thames, **A. Wisthaler**, M. Müller, T. Mikoviny, A. Weinheimer, T. Mikoviny, M. Yang, J.-H. Woo, S.-Y. Kim, H. Park, The roles of suburban forest in controlling vertical trace gas and OH reactivity distributions – a case study for Seoul Metropolitan Area, Faraday Discuss., 10.1039/D0FD00081G, accepted (2020)

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Preparing for winter sampling in Sætertjenn (Photo by Nicolas Valiente Parra)

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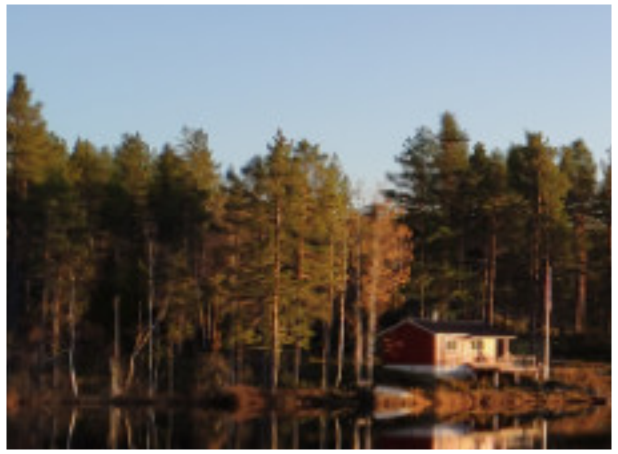

Sønstevatn, Telemark. Photo by Nicolas Valiente Parra.

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PEOPLE AT CBA

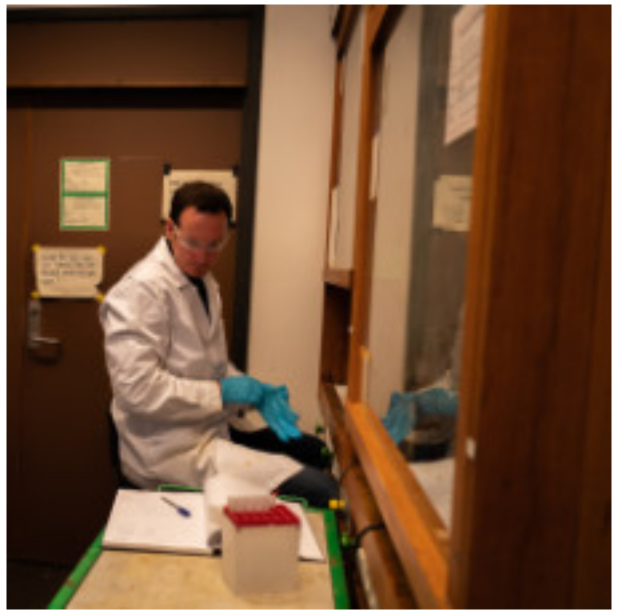
LEADER GROUP AND BOARD

First name	Last name	Nationality	Position	Department	Section
Dag Olav	Hessen	Norwegian	Professor / centre leader	Biosciences	Aquatic Biology and Toxicology
Terje	Berntsen	Norwegian	Professor / leader group	Geosciences	Meteorology and Oceanography
Rolf David	Vogt	American	Professor / leader group	Chemistry	Environmental Sciences
Brit Lisa	Skjelkvåle	Norwegian	Head of department / board	Geosciences	
Rein	Aasland	Norwegian	Head of department / board	Biosciences	
Einar	Uggerud	Norwegian	Head of department / board	Chemistry	
Solveig	Kristensen	Norwegian	Dean / board		
Lene	Liebe Delsett	Norwegian	Centre coordinator	CBA	

Participants of the annual meeting 2020 at Reenskaug hotel in Drøbak.

SENIOR RESEARCHERS

First name	Last name	Nationality	Position	Department	Section
Trude	Storelvmo	Norwegian	Professor	Geosciences	Meteorology and Oceanography
Anders	Bryn	Norwegian	Associate Professor	Natural History Museum	Geo-Ecology Research Group
John	Burkhart	Norwegian	Associate Professor	Geosciences	
Alexander	Eiler	Austrian	Professor	Biosciences	Aquatic Biology and Toxicology
Helge	Hellevang	Norwegian	Professor	Geosciences	Section of Physical geography and Hydrology
Sebastian	Westermann	German	Associate Professor	Geosciences	Section of Physical geography and Hydrology
Katrine	Borgå	Norwegian	Professor	Biosciences	Aquatic Biology and Toxicology
Anne Hope	Jahren	American	Professor	Geosciences	Earth Evolution and Dynamics
Kirstin	Krüger	Norwegian	Professor	Geosciences	Meteorology and Oceanography
Lena Merete	Tallaksen	Norwegian	Professor	Geosciences	Section of Physical geography and Hydrology
Tom	Andersen	Norwegian	Professor	Biosciences	Aquatic Biology and Toxicology
Kjetil	Schanke Aas	Norwegian	Researcher	Geosciences	Meteorology and Oceanography
Elisabeth	Alve	Norwegian	Professor	Geosciences	Geology and geophysics
Eddy Walther	Hansen	Norwegian	Professor	Chemistry	Environmental Sciences
Jon Petter	Omtvedt	Norwegian	Professor	Chemistry	Environmental Sciences
Armin	Wisthaler	Austrian	Professor	Chemistry	Environmental Sciences
Heleen	de Wit	Dutch	Associate Professor	NIVA	
Frans-Jan	Parmentier	Dutch	Researcher	Geosciences & Lund University	Meteorology and Oceanography
Norbert	Pirk	German	Researcher	Geosciences	Section of Physical geography and Hydrology


Alexander Håland preparing to process some samples.

RESEARCHERS, POSTDOCTORAL RESEARCHERS, AND EMERITI

First name	Last name	Nationality	Position	Department	Section
Frode	Stordal	Norwegian	Professor emeritus	Geosciences	Meteorology and Oceanography
Knut	Breivik	Norwegian	Professor II	Chemistry	Environmental Sciences
Kari	Kveseth	Norwegian	Senior Executive Officer	Chemistry	Environmental Sciences
Jan	Heuschele	German	Researcher	Biosciences	Aquatic Biology and Toxicology
Heidi	Konestabo	Norwegian	Researcher	Biosciences	Aquatic Biology and Toxicology
Ane Victoria	Vollsnes	Norwegian	Researcher	Biosciences	Genetics and Evolutionary Biology
Henrik	Svensen	Norwegian	Researcher	Geosciences	Centre for Earth Evolution and Dynamics
Yeliz	Yilmaz	Turkish	Postdoctoral fellow	Geosciences	Section of Physical geography and Hydrology
Thea	Heimdal	Norwegian	Postdoctoral fellow	Geosciences	Centre for Earth Evolution and Dynamics
Nicolas	Valiente Parra	Spanish	Postdoctoral fellow	Biosciences	Aquatic Biology and Toxicology
You-Ren	Wang	Taiwanese	Postdoctoral fellow	Biosciences	Aquatic Biology and Toxicology
Andrea	Popp	German	Postdoctoral fellow	Geosciences	Geology and geophysics
William	Hagopian	American	Engineer	Geosciences	Centre for Earth Evolution and Dynamics

DOCTORAL RESEARCH FELLOWS

First name	Last name	Nationality	Position	Department	Section
Lina	Allesson	Swedish	Doctoral Research Fellow	Biosciences	Aquatic Biology and Toxicology
Sara Marie	Blichner	Norwegian	Doctoral Research Fellow	Geosciences	Meteorology and Oceanography
Camille	Crapart	French	Doctoral Research Fellow	Chemistry	Environmental Sciences
Ane	Haarr	Norwegian	Doctoral Research Fellow	Biosciences	Aquatic Biology and Toxicology
Maja	Nipen	Norwegian	Doctoral Research Fellow	Chemistry	Environmental Sciences
Elin Cecilie	Ristorp Aas	Norwegian	Doctoral Research Fellow	Geosciences	Meteorology and Oceanography
Sabrina	Schultze	German	Doctoral Research Fellow	Biosciences	Aquatic Biology and Toxicology
Jing	Wei	Chinese	Doctoral Research Fellow	Biosciences	Aquatic Biology and Toxicology
Lars-André	Erstad	Norwegian	Doctoral Research Fellow	Geosciences	Section of Geology and Geophysics
Laurent	Fontaine	Canadian	Doctoral Research Fellow	Biosciences	Aquatic Biology and Toxicology
Alexander	Håland	Norwegian	Doctoral Research Fellow	Chemistry	Environmental Sciences
Aleksandr	Berezovski	Lithuanian	Doctoral Research Fellow		
Marius	Lambert	Belgian	Doctoral Research Fellow	Geosciences	Meteorology and Oceanography
Christina	Nadeau	Norwegian	Doctoral Research Fellow		
Juditha	Schmidt	German	Doctoral Research Fellow	Geosciences	Physical geography and Hydrology

Master student Elisabeth Emilie Syse performing a field calibration with amine solution (Photo by Alexander Håland)

ECONOMY 2020

CBA is financed through overhead from research projects and contributions from the three departments involved:
Biosciences, geosciences and chemistry. CBA started running in 2018, and has had its two first complete running years in 2019 and 2020. So far, most of the projects as well as staff are housed at the individual departments. The aim is to attract funding for a growing number of projects housed at CBA, through 2021 and the years to come.

INCOME	NOK
Transferred from 2019	63169
Contributions from the departments (BIO, GEO, & CHEMISTRY)	661590
Overhead from projects	256229
Total income	980988
COSTS	
Salary (centre coordinator)	416144
Other running costs	233795
Total expenditure	649939
NET RESULT	331049

Centre for Biogeochemistry in the Anthropocene

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