Bolin Centre for Climate Research

Annual Report 2023–2024

Including research highlight articles:

Bolin Centre Mission

Bolin Centre Mission: The mission of the Bolin Centre is to create and communicate fundamental knowledge about the coupled climate system and its interactions with life on Earth in the past, present, and future, and to connect this knowledge to effective societal actions.

Bolin Centre Vision

Bolin Centre Vision: Our vision is for the Bolin Centre to be a thriving research environment at the international forefront, uniting experts across disciplines, training future generations of climate scientists, and delivering climate knowledge that supports societal action to mitigate and adapt to climate change.

Cover photo: Martin Jakobsson
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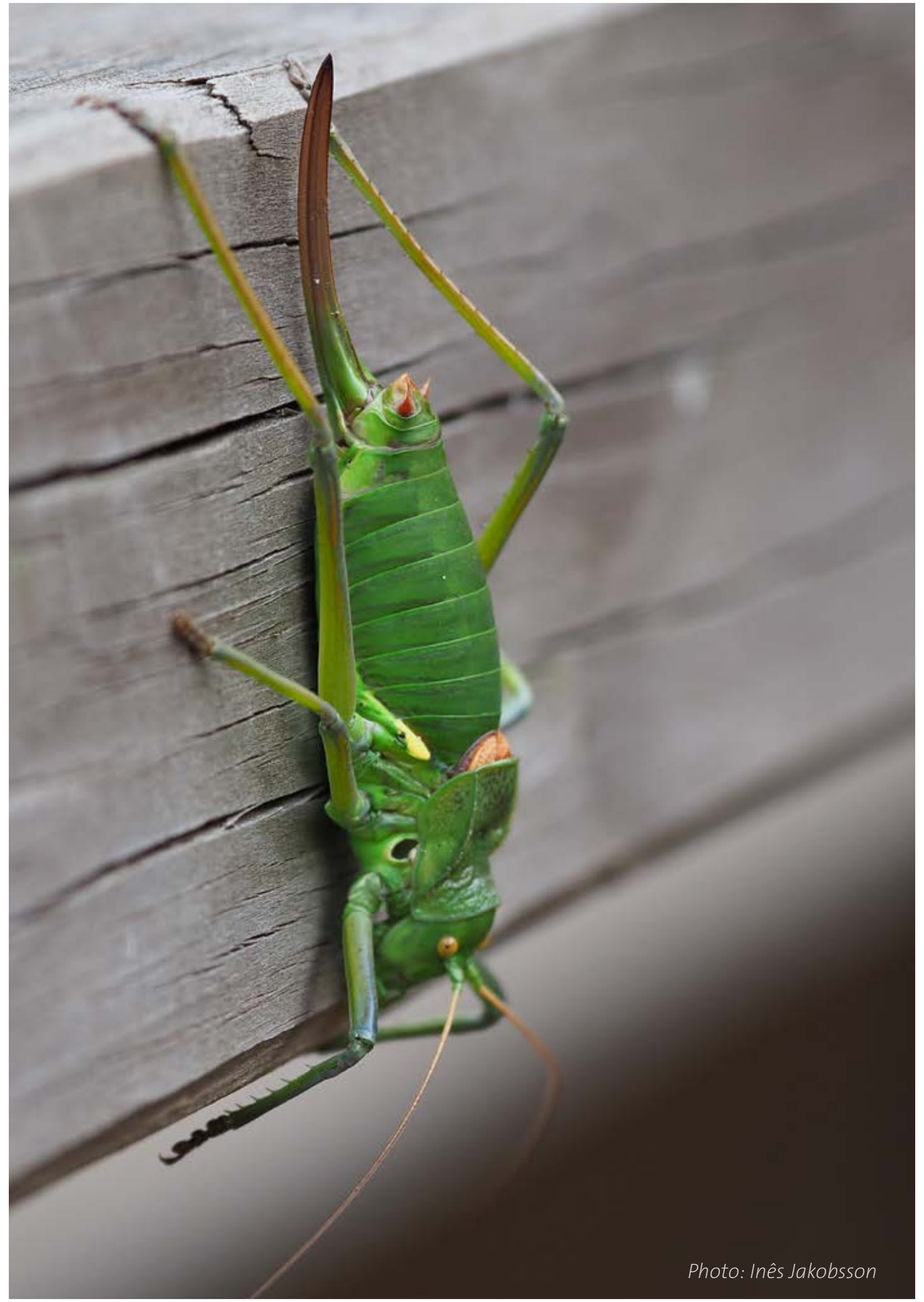


Photo: Inês Jakobsson

The Bolin Centre for Climate Research

The Bolin Centre is a multi-disciplinary consortium of more than 400 scientists in Sweden who conduct research, graduate education, and outreach related to the Earth's climate. It was formed in 2006 by Stockholm University, and in 2010 the KTH Royal Institute of Technology and the Swedish Meteorological and Hydrological Institute joined the centre. The Bolin Centre is named in honour of Professor Bert Bolin of Stockholm University, a world leader in climate and carbon cycle research.

The Bolin Centre focuses on extending and disseminating fundamental knowledge about the coupled climate system and its interactions with life on Earth; climate-impacting processes; climate modelling; human impact on the climate; and climate impacts on ecosystems, biodiversity, and humanity; as well as the ways in which society can minimise the negative impacts of climate change. It contributes to the knowledge base on climate mitigation and adaptation policies nationally and internationally.

The Bolin Centre is named after Professor Bert Bolin of Stockholm University, one of the founders of the Intergovernmental Panel on Climate Change (IPCC). The work of the IPCC and others led to recognition of the need for cross-disciplinary collaboration on climate science at Stockholm University. This resulted in a Climate Research School being established in 2005, and shortly thereafter, in 2006, the SUCLIM (Stockholm University Climate Research Centre) research programme was awarded a 10-year Linnaeus Grant by the Swedish government.

In 2008, SUCLIM was renamed the 'Bert Bolin Centre for Climate Research', a name which was afterwards shortened to the 'Bolin Centre for Climate Research' in 2013. In 2010, the Swedish Hydrological and Meteorological Institute and the KTH Royal Institute of Technology joined the Bolin Centre in a collaboration aimed at strengthening climate modelling within the centre. This initiative was funded as a strategic research area by the Swedish government.

In June 2016, the Bolin Centre merged with another strategic research area at Stockholm University: EkoKlim, a multiscale, cross-disciplinary approach to the study of climate change on natural resources, ecosystem services, and biodiversity. This merger widened the scope of the Bolin Centre to include the impacts of climate change on landscape processes and biodiversity. As a result of the merger, the Bolin Centre's strategic funding now surpasses 20MSEK per year.

In early 2023, the Bolin Centre completed a process of redefining its strategic plan and strategic goals for 2023–2027. This collaborative initiative aimed to redefine priorities and unite leadership, Research Theme leaders, and active members in discussions of the centre's essentials and its future development path.

Bolin Centre for Climate Research
A collaboration between Stockholm University, KTH, and the Swedish Meteorological and Hydrological Institute.

Stockholm University KTH Vetenskap och Konst SMHI

Bolin Centre organisation

The Bolin Centre aims to bring climate scientists together. The centre follows four Research Themes (RTs), where scientists from different disciplines come together to tackle key questions about climate. The Bolin Centre organises seminars, workshops, conferences, outreach projects and research education.
The Bolin Centre aims to foster collaboration and interdisciplinary research among climate scientists. To this end, the centre has established four Research Themes that bring together experts from diverse fields to address key questions related to climate. In addition, the Bolin Centre organises a range of activities, such as seminars, workshops, conferences, and outreach projects, and also provides research education opportunities.

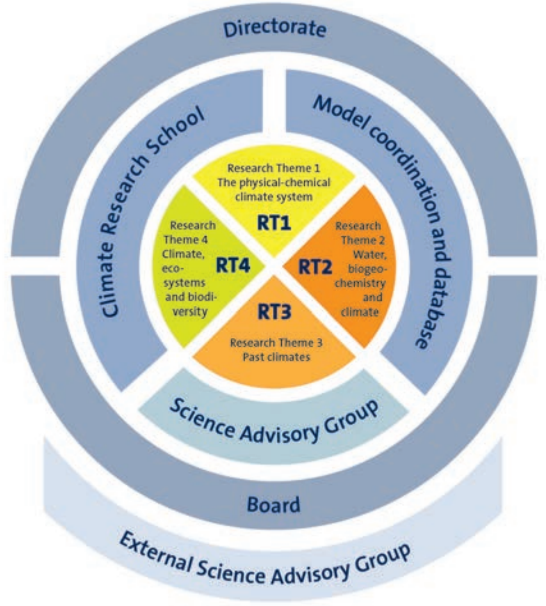
The Bolin Centre is built around its four multi-disciplinary Research Themes, each of which is led by two (or three) scientists:

Research Theme 1 | The physical-chemical climate system
Research Theme 2 | Water, biogeochemistry and climate
Research Theme 3 | Past climates
Research Theme 4 | Climate, ecosystems and biodiversity.

The centre hosts a research school and an open-access database and also provides communication support and support for climate modelling activities.

The directorate consist of a director, a co-director and a coordinator, who share the centre's daily tasks. All Research Themes' co-leaders and the directorate meet regularly in the Science Advisory Group, working to support climate-related science conducted by the Bolin Centre members.

The Bolin Centre is led by its board, which includes heads of participating departments at Stockholm University, representatives from KTH Royal Institute of Technology and the Swedish Hydrological and Meteorological Institute, and external members. The Bolin Centre receives guidance from its External Science Advisory Group. These internationally recognised leaders in climate science aim to visit the Bolin Centre annually at its internal conference: the Bolin Days.



The operational philosophy of the Bolin Centre is one of mutual respect and trust – a philosophy which is reflected in the form of paired leadership, which is applied throughout the organisation.

Bolin Centre directors' corner

The Bolin Centre has evolved from an idea among a few inspired individuals to a thriving research hub with more than 400 scientists focusing on science, education and outreach activities related to the Earth's climate.
The Bolin Centre is a common effort, and its success is the success of its members.

The year 2023 broke the record as the warmest ever measured, with a temperature anomaly almost 1.5 degrees over the preindustrial period. There was record-low sea ice extent around Antarctica and numerous extreme events observed around the world, including heatwaves, droughts, floods, and wildfires. While the awareness that humanity must act to avoid even more dire consequences for society and ecosystems is growing, the need for basic climate science is not decreasing. On the contrary, we need to improve our fundamental understanding of the coupled Earth system, the interactions between its compartments, and the impacts it will have for on life of earth. Designing safe and effective measures for climate change mitigation and adaption requires deep knowledge of these intricate connections—much like finding a medical treatment requires correct diagnosis and knowledge about the right dose, side effects, and potency of the proposed medicine.

Researchers in the Bolin Centre have worked tirelessly on many fronts to advance our understanding of the Earth system: from investigating the atmosphere and ocean in the high Arctic (see the description of the ArtOfMelt expedition, p. 14) to observations of coffee trees on the African continent (see p. 26); from studies on the role of water in forest microclimates (see p. 28) to global wetlands (see p. 18); and analysing the family trees of the climate models (see p. 16) on which IPCC future projections are ultimately based upon. Our researchers' capacity to push forward research frontiers and pursue highly relevant research questions has been acknowledged by the success Bolin members have had in acquiring highly competitive external funding for their work; e.g., in the annual calls of FORMAS, Vetenskapsrådet, the Knut and Alice Wallenberg foundation, and the European Commission. During the past academic year, we have also recruited our first four Bolin post-doctoral fellows, representing the breadth of the research fields present in our Centre. We were very impressed by the applicants for these fellowships and look forward to seeing what these excellent early career researchers will discover and share with the rest of us during their time at the Bolin Centre.

Supporting transparent, reproducible, and accessible science is one of the strategic focal points of the Bolin Centre. To this end, the Bolin Centre Database has continued is successful development, hosting nearly 500 atmospheric, marine, terrestrial, and lacustrine datasets. The Bolin Centre modelling coordination team has taken an active role in the user community of the newly-reorganised National Academic Infrastructure for Supercomputing in Sweden (NAISS). Another exciting development is our engagement in the future of the locally-driven, non-profit scientific journal 'Tellus'. This is a Stockholm University journal, originally founded by Carl-Gustaf Rossby, and for some time Bert Bolin himself was the editor in chief. Tellus is a real gem of a journal, with 75 years and numerous seminal Earth system science studies in the bag—stay tuned for more news on anniversary celebrations and other future developments in the coming academic year!

The board of the Bolin Centre has a new chair, Regina Lindborg, and the board is continuing to conduct its work in a positive and supportive atmosphere. We have also had the pleasure of welcoming Laila Islamovic back to the Bolin Centre directorate, with external communication as her primary area of responsibility. She has enhanced our communication activities, ensuring regular news updates on our website and spearheaded the development of a strategic communication plan for the Bolin Centre. External communication by the Bolin Centre, including strengthening its international visibility, is in high demand, with numerous opportunities to interact with external stakeholders. A strategic approach to our communication is therefore a necessity, given the resources that we have for it at present. We have been delighted to see the Bolin Centre researchers featured as experts more than 24 times during 2023 in various leading national and international media. In our responses to requests from the media, we have strived to direct requests to the centre members with the best possible expertise on the topic in question. To ensure the continued visibility of the Bolin Centre, we would like to take the opportunity to remind our members to add the Bolin Centre as their affiliation in both their research as well as their outreach activities.

While the rapid change in our environment often feels dire with all its future uncertainties and threats, it remains rational to believe in the ability of the humankind and the rest of the biosphere to tackle this challenge. This requires keeping our eyes on the horizon, our minds open to renewal and our hearts in whatever we do. Looking forward to tackling new challenges with you in the coming year—thank you for your support and hard work!

Ilona Riipinen and Gustaf Hugelius,
co-directors of the Bolin Centre.
Photographer: Sören Andersson

Publications

The total number of publications where researchers have listed an affiliation to the Bolin Centre in 2023 is around 400. The total number of publications by researchers (listed as Bolin-members on our website) in 2023 is around 700.

The Bolin Centre Database

The Database promotes research results and visualises data. As of December 2023, the Database hosts 390 datasets and several thematic data collections and interactive visualisations. Read more on page 32.

Communication channels

Visit *www.bolin.su.se* and follow us on Facebook, *LinkedIn*, and 𝕏 (*@BolinCentre*) and for the latest news and events.

Photo: Maria Basova

Bolin Centre's Strategic Goals for 2023–2027

Bolin Centre seeks to expand its influence across climate-related research disciplines and within Earth System science via the following strategic goals:

Resources

To secure the necessary resources to reach the strategic goals below, including: (i) long-term base funding to sustain the breadth of our research fields and enhance integration across them, particularly in relation to the biosphere component of the Earth system and support infrastructures; (ii) new investments into strategic partnerships; and (iii) external competitive grants raised by Bolin Centre PIs.

Local, regional and national partnerships

To be an integrated key part of the larger research environment for climate and sustainability in Sweden. Regionally, the research and outreach at the Bolin Centre will be aligned with the strategic goals of Stockholm University, the Royal Institute for Technology, the Swedish Meteorological and Hydrological Institute, and synergistic with other collaborating centres.

Integration

To further enhance internal communication and integration of the research within the Bolin Centre, providing an environment that promotes scientific inquiry and output of high-quality peer-reviewed publications, fostering collaboration among Bolin Centre members and RTs.

Infrastructure

To further develop the national landscape for technical support of climate research, including science infrastructures for modelling, observation, and data science as well as the open, fair and transparent publication of scientific data and knowledge in collaboration with other relevant Swedish and international research environments.

Career opportunities

To host a vibrant and diverse community of climate researchers and offer a research environment that sustains their further development. We build a foundation for future employment opportunities for early career researchers through networking and exposure to diverse career pathways. We support and strengthen the recruitment of staff to SU, KTH, and SMHI and offer attractive possibilities for international researchers to visit our research environment.

External communication.

To have a strategic approach to external communication that optimally addresses the growing demand for our expertise by various stakeholders, with a particular focus on future generations of experts, decision-makers, and society members.

Illustration: Inês Jakobsson

Bolin Centre is an active participant in the University Alliance Stockholm Trio in 2023

In 2019, Karolinska Institutet, KTH, and Stockholm University formed the University Alliance Stockholm Trio, a collaborative effort to develop and highlight the internationally prominent research and education environment that the three universities represent in the Stockholm region.

In May 2023, the Bolin Centre, along with partners—the KTH Climate Action Centre and the KI Centre for Health Crises—participated in a **seminar in Brussels** organised by the Stockholm Trio Brussels office. With Vice Director Gustaf Hugelius of the Bolin Centre present in person, the seminar was a reflective exploration of the link between knowledge gain and crisis management, drawing parallels between the lessons learned from the COVID-19 pandemic and the imperative strategies required to mitigate climate-related risks. Held under the auspices of the Swedish Presidency of the European Council, the seminar attracted around 40 attendees, including representatives from the European Commission, the European Research Executive Agency, and several university and research organisations and networks, including UNICA (Network of Universities from the Capitals of Europe). The seminar provided a valuable platform for presentations and discussions, catalysing an exchange of ideas that transcend disciplinary boundaries. Moreover, it served as a compelling testament to the collective endeavours of the Stockholm Trio, spotlighting our collaborative endeavours within the broader European Union network and beyond. As we navigate the complexities of our shared climate future, such collaborative initiatives underscore our adamant commitment to effecting positive change on a global scale.

The Symposium on Climate and Health, held on November 21, 2023, offered a comprehensive exploration of the intricate relationships between climate and public health. The event—organised by the Health Committee of the Royal Swedish Academy of Sciences in collaboration with Bolin Centre for Climate Research and Stockholm Trio partners—included insightful discussions across four key sessions: Temperature, Air, Water, and Food. Experts provided in-depth analyses of the impacts of a warming world, changes in temperature, air quality scenarios, and the critical role of water in the context of global climate policies. Additionally, discussions delved into the link between dietary health, environmental impact, and food security. Plenary sessions provided valuable overviews and emphasised the importance of climate mitigation and adaptation for promoting health benefits. The symposium not only summarised the current state of scientific understanding but also aimed to stimulate discussions contributing to ongoing and future policy processes. The event's success is evident in its ability to bring together multidisciplinary expertise, promoting collaboration to address the challenges and co-benefits associated with climate and health. The symposium laid the groundwork for a follow-up event in 2024, dedicated to exploring best practices, policies, and solutions in this critical intersection of climate science and public health.

In 2023, the annual Bolin Days Conference included a session highlighting collaboration within the Stockholm Trio for Sustainable Actions, involving the Stockholm Trio's Working Group representative from SU, Magnus Breitholtz, KTH Climate Action Centre, the KI Centre for Health Crises, and the KI Centre of Excellence for Sustainable Health. During this session, insights were shared by Petter Ljungman (KI) and Francesco Fuso Nerini (KTH), as well as Nina Viberg (KI), showcasing the work conducted by the three centres. The event served as a platform to explore and continue the emerging collaboration between these institutions, fostering a deeper understanding of their collective contributions to addressing climate and health challenges and their interlinkage. The Bolin Centre expressed gratitude to all contributors and anticipates continued cooperation in future endeavours.

Photo: Björn Olin

The Bolin Centre Research Themes

Until the end of 2021, the research was structured into eight multi-disciplinary research areas (you can read more about them on our website). Since the beginning of 2022, the Bolin Centre has been reorganised into four Research Themes with the following titles:

Research Theme 1 | The physical-chemical climate system

Research Theme 1 addresses some of the major knowledge gaps in the physical–chemical climate system. Covering a range of scales, we study aerosols and clouds; the dynamics of the atmosphere, ocean, and cryosphere; the risk of reaching climate system tipping points and regional effects of global warming; and climate sensitivity and the carbon budget. We develop and use tools ranging from Large Eddy Simulation to Earth system models, and from in-situ observations to satellite and reanalysis products.

Co-leaders:
Torben König, Swedish Meteorological and Hydrological Institute (SMHI)
Thorsten Mauritsen, Dept. of Meteorology, Stockholm University
Frida Bender, Dept. of Meteorology, Stockholm University

Research Theme 2 | Water, biogeochemistry and climate

Research Theme 2 studies the coupled water and biogeochemical cycles and their interactions with climate and society over multiple spatial and temporal scales. Our ultimate goal is to define the adaptation necessary to address climate risks related to these cycles and to guide policy toward the mitigation of these risks. For this task, we rely on field- and space-based observations, modelling, monitoring, and experiments on land, in the ocean, and in the atmosphere.

Co-leaders:
Fernando Jaramillo, Dept. of Physical Geography, Stockholm University
Volker Brüchert, Dept. of Geological Sciences, Stockholm University

Research Theme 3 | Past climates

Research on past climates encompasses climate variability on tectonic, orbital, millennial, centennial, and historical timescales. We use a wide range of geoscientific data to reconstruct the evolution of the climate system, including its landscapes and ecosystems, from local to global scales. Climate models are used to simulate extreme climate states in the past, and to study impacts, mechanisms, and feedback operating in the climate system under different climate forcings. Past climates provide a thorough test of models to project future changes in a confident way.

Co-leader:
Frederik Schenk, Dept. of Geological Sciences, Stockholm University (SU)
Fredrik Charpentier Ljungqvist, Dept. of History, Stockholm University
Natasha Barbolini, Dept. of Ecology, Environment and Plant Sciences, SU
Margret Steinthorsdottir, Swedish Museum of Natural History, affiliated with Dept. of Geological Sciences, Stockholm University.

Research Theme 4 | Climate, ecosystems and biodiversity

Research on climate, ecosystems, and biodiversity at the Bolin Centre aims to understand how the climate affects ecological, evolutionary, and biophysical processes, as well as to understand the possible feedback of these processes on climate and human use of land and water. The research relies on using field observations, experiments, and modelling to examine the effects of the climate on different aspects of ecosystems and biodiversity.

Co-leaders:
Stefano Manzoni, Dept. of Physical Geography at Stockholm University
Rhonda Snook, Department of Zoology, at Stockholm University

Please note that the list of SAG RT co-leaders is accurate as of December 2023. Later changes to the SAG leadership may have occurred. The most up-to-date information can be found on our website: *https://www.su.se/bolin-centre-for-climate-research/about-the-centre/organisation*

RT1 | ARTofMELT – A Stockholm University led expedition to investigate the role of Atmospheric rivers and the onset of Arctic melt

The collective global warming effects are larger in the Arctic than elsewhere on Earth, and for many aspects observed trends fall well outside expectations, considering current understanding and modelling skills. Much of these deficiencies are due to a lack of observations needed to better our understanding. The lengthening of the sea ice melt season is one aspect, especially the so-called shoulder seasons; the onsets of melt and freeze. The onset of the melt is especially difficult to observe. Most Arctic research expeditions occur in August and September when the ice is much easier to navigate than at the end of winter, because of the summer melt.

ARTofMELT was designed to alleviate this, targeting two aspects: first the onset of the sea ice melt itself but also so-called 'atmospheric rivers' (ARs). ARs are filaments of warm and moist air propagating into the Arctic and are associated with weather systems. The hypothesis was that the melt onset timing is governed by such AR events. To test this, ARTofMELT had to navigate the Arctic in late winter ice and also be able to position measuring systems and sampling devices to where ARs would appear. This navigation was facilitated by a virtual forecast centre set up at MISU, Stockholm, and at the European Centre for Medium Range Weather forecasts in Reading, UK, who provided daily forecast guidance.

After intense preparations, the Swedish research icebreaker *Oden* left Longyearbyen, Svalbard, on May 8, 2023, heading north with 38 ARTofMELT scientists onboard, representing 10 nations from 19 universities or research institutes, also supported by onshore scientists from another 3 institutes. The Swedish Polar Research Secretariat supplied 13 support staff while *Oden*'s crew comprised another 23, totalling 74 individuals going into the Arctic to experience spring together. An underlying strategy was to cover a column starting in the upper ocean, up through ice and snow, to the top of the troposphere. As you need to be nimble to catch ARs, the core of the observations had to be made from *Oden*, but the plan also included mooring to ice floes to take measurements on the ice when ARs were encountered. The program was dominated by atmospheric science (meteorology, atmospheric chemistry, and physics) but also included work packages on oceanography, biogeochemistry, sea ice, and snow, and geophysical mapping was also conducted. In addition to the ship itself and the ice camps, a helicopter was used to transport scientists to nearby ice floes to sample snow and ice and to deploy the Helipad, an airborne instrument package with an extensive suite of instruments. The Helikite, a tethered and instrumented balloon, was deployed from *Oden*'s aft, and while researchers were at the ice camps, an underwater robot was surveying the ice from below.

Group photo of all participants in ARTofMELT. Photo: Paul Zieger

Research icebreaker Oden moored to an ice floe in the Fram Strait, to allow for work on the ice while receiving the first atmospheric river. Note the Helipad flying from the aft. Photo: Michael Tjernström

When the expedition ended in Longyearbyen on June 14, 2023 we had experienced only two AR, but the second triggered the onset of the melt, on June 10, 2023. AR episodes were fewer in number than expected but we also experienced two strong storms. The ice was much more difficult to navigate than expected and caused ARTofMELT to remain in the Fram Strait sea ice rather than situate itself farther north. Despite these setbacks, we covered relevant processes in all spheres from late winter through to the melt, collecting a wealth of unique observations and samples that will keep the science team occupied for years. The transition from winter to summer is more complex than first believed, and one main discovery was that it appeared under the ice before becoming obvious at the surface. We observed the onset of the spring algal bloom below the ice weeks before the surface reached melt; melt first occurred from below. While the surface melt onset was indeed triggered by an AR, the upper ocean and the ice was preconditioned by increasing solar radiation. A question for the future is how these timings are interconnected; what would have happened if the triggering AR had come earlier—or later?

ARTofMELT was co-lead by MISU and ACES.

RT1 | Code genealogy of climate models constructed

Almost ever since the advent of computers, climate models have been developed to simulate the Earth's climate. First, models were developed to scientifically understand the climate system and later to also understand climate change and predict future climate depending on greenhouse gas and aerosol emissions. Early climate models simulated only the atmosphere, later models added the ocean, and modern climate models, called 'Earth system models', also simulate the cryosphere; biosphere, and chemical processes in the atmosphere and ocean. Many countries started developing one or more state-funded climate models through research institutes. Over time, hundreds of such models have been developed, often borrowing computer code from one another. The immense complexity and size of the code often make starting a new model from scratch prohibitively expensive and time-consuming. This has led to a maze of model relationships, which until now have not been properly studied.

Many climate studies today rely on results coming from a set of models called a 'model ensemble'; for example, by averaging the results of multiple models. This serves as protection from the deficiencies of any single model, but also allows scientists to quantify the uncertainty in their results and capture a greater amount of variability due to our uncertainty about climate processes and how to simulate them on a computer, with each model representing them differently. Including multiple models that share code in such an ensemble then leads to a certain amount of dependency, and certain groups of models sharing substantial amounts of code can be over-represented in the ensemble. Ideally, this should be known and quantified, and over-representing models should be avoided.

In our study, we constructed a code genealogy, or 'family tree', of 167 atmosphere-only, atmosphere–ocean, and Earth system models spanning several decades, including all models participating in the Coupled Model Intercomparison Project (CMIP) phases 3, 5, and 6. We have found that all of the studied models trace their history back to about 14 ancestral models, forming 14 model families. Within each family, models often tend to produce similar results, such as global temperature, so-called 'climate feedbacks', and sensitivity of temperature to greenhouse gas concentrations. We have found that only 3 model families comprise about 70% of all models in the latest CMIP phase.

We propose statistical weighting which takes into account the code relationships between models, so that, for example, more balanced averages can be calculated from model ensembles. This is in contrast to a simple 'model democracy', where every model in an ensemble is given the same statistical weight, as in 'one model, one vote', which would be only truly applicable if all models were completely independent.

When constructing the genealogy, our focus was on the component of models simulating the atmosphere, but a similar genealogy could be constructed with a focus on the ocean-simulating component. This was motivated by the fact that cloud processes are currently the leading source of uncertainty in future climate projections.

The projected sensitivity of temperature to greenhouse gases has increased on average in the latest generation of CMIP models. Our results contribute to explaining a part of this increase. Models in families with high sensitivity have proliferated more in the latest phase of CMIP compared to other model families and therefore have a greater weight in the overall result, even though they are often closely related. Our proposed weighting, accounting for dependencies, reduces the difference between the latest and the previous generation of CMIP models.

Future research could extend our analysis to the ocean component, quantify the strength of code relationships between models, or look at how the identified model families differ in their simulations of different aspects of the climate system. Overall, this could help explain why climate models do not always agree on their results, and thus reduce our uncertainty in future climate projections.

Our work was done at the Department of Meteorology and Bolin Centre for Climate Research at Stockholm University, and funded by the EU projects FORCeS and NextGEMS and the Swedish e-Science Research Centre. The results have been published in the Journal of Advances in Modelling Earth Systems (*https://doi.org/10.1029/2022MS003588*).

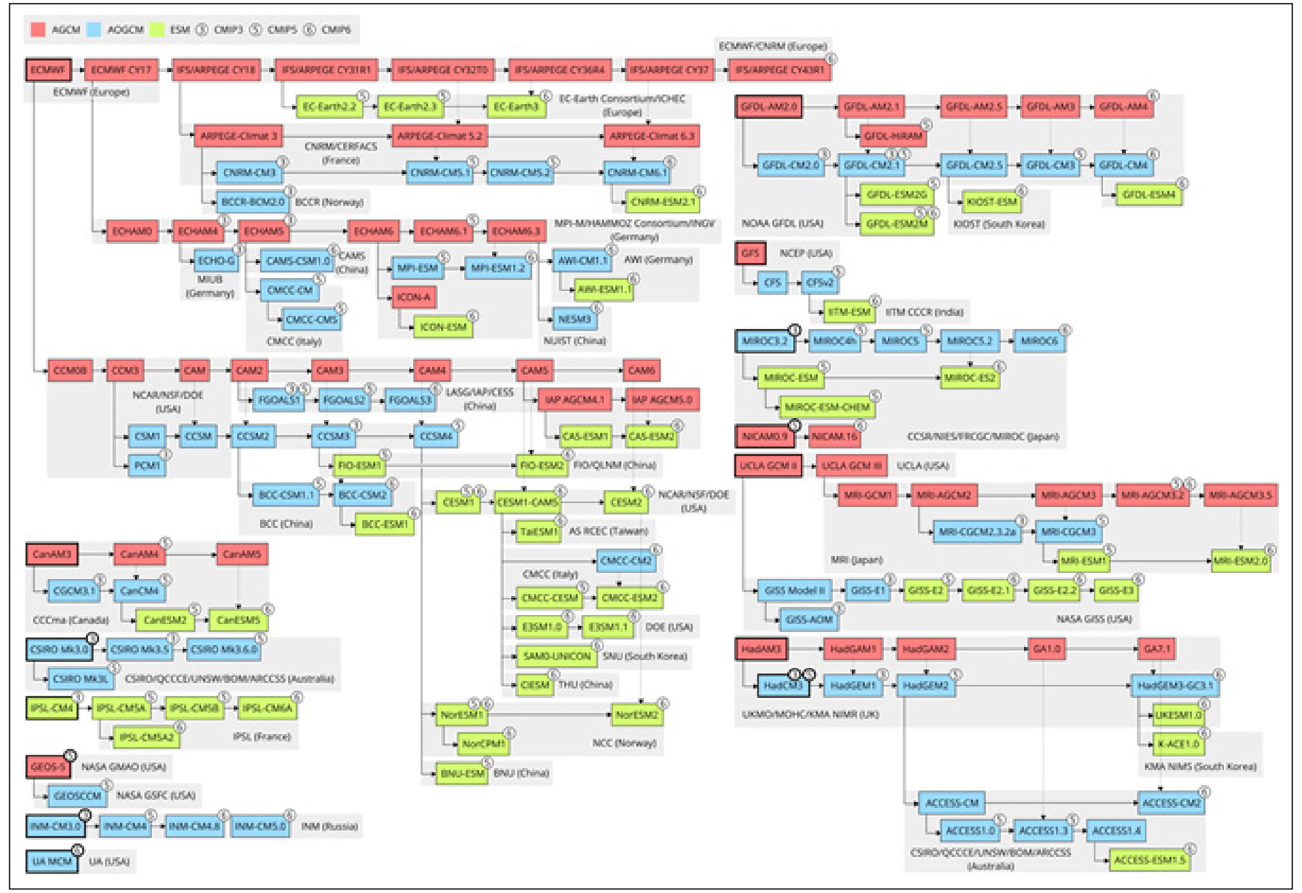


Figure from Kuma et al.(2023) illustrating the model code genealogy of models participating in the Coupled Model Intercomparison Project (CMIP) phase 3, 5, and 6, including their common ancestor models.

RT2 | Understanding the Impact of Remote Land-Use Changes on Wetland Hydrology

Wetlands are experiencing intense decline due to various factors, including climate change and human activities such as agricultural expansion, fragmentation by road infrastructure, water impoundment, and freshwater withdrawals for irrigation. Historically, research has focused on local and immediate threats to wetlands, such as pollution, direct land conversion, and water diversion. However, there is growing recognition that remote land-use changes, particularly those affecting upwind atmospheric moisture supply, can significantly influence wetland hydrologic regimes. Understanding these impacts is crucial, as they can alter precipitation patterns and moisture recycling, leading to changes in water availability and, consequently, wetland functionality.

A study by Fahrländer et al. (2024) evaluates the vulnerability of 40 wetlands protected by the Ramsar Convention and their hydrological basins to upwind precipitation shifts caused by land-use and hydroclimatic changes. The study investigates the precipitation source regions of these wetlands with a comprehensive approach that maps where precipitation predominantly comes from, its relationship to historical global land use change, and the hydroclimatic changes recently experienced by the wetlands. This approach allows us to assess how changes in upwind regions influence wetland moisture supply, which is a critical factor in maintaining their hydrologic balance and overall health

Fahrländer et al. (2024) use a dataset of atmospheric moisture trajectories generated with the Lagrangian atmospheric moisture tracking model UTrack to trace the sources of atmospheric moisture contributing to precipitation in selected wetlands. They combine this model output with atmospheric reanalysis data, land use, and modelled evaporation and precipitation data to map the precipitation sources given their current land use and analyse changes in moisture supply through anthropogenic land use change. The results are then combined with trends in runoff, expressed as *P–E*, in a vulnerability indicator to assess the wetlands hydroclimatic vulnerability to upwind land use change.

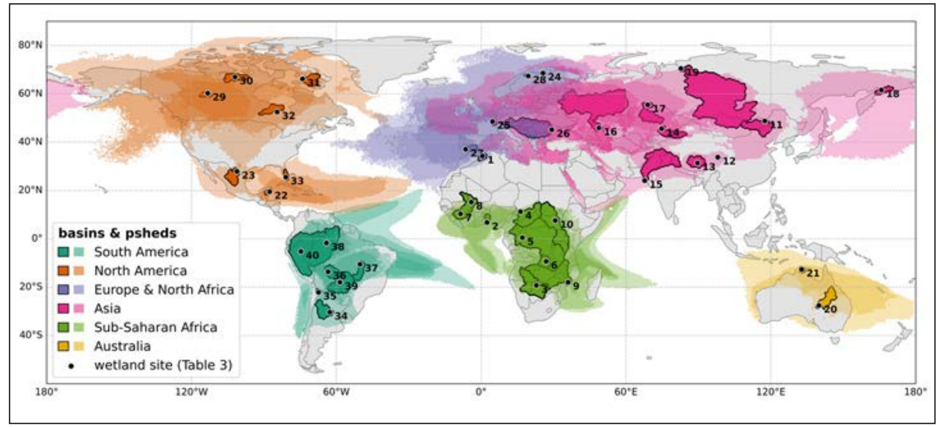
They find that for 30 of the 40 wetlands, terrestrial sources contribute to at least half of the total annual precipitation. Notably, coastal wetland basins show the lowest terrestrial precipitation recycling ratios, primarily receiving ocean moisture. However, even these basins rely on land evaporation for 17%–23% of their annual precipitation. The findings reveal that historical land use changes have significantly reduced precipitation and moisture recycling in many regions, decreasing water availability in some wetlands. Regions such as Central Europe face substantial impacts to their hydrologic regimes due to high precipitation recycling ratios and significant land use changes.

The study also identifies ‘hotspot’ wetlands in South America and Central Asia which are particularly vulnerable. These regions exhibit a marked decrease in runoff and precipitation, driven by land-use-induced runoff impacts and climatic change. The declining surface water availability in these wetlands underscores the critical need to understand how climate change and land use changes impact ecosystems worldwide.

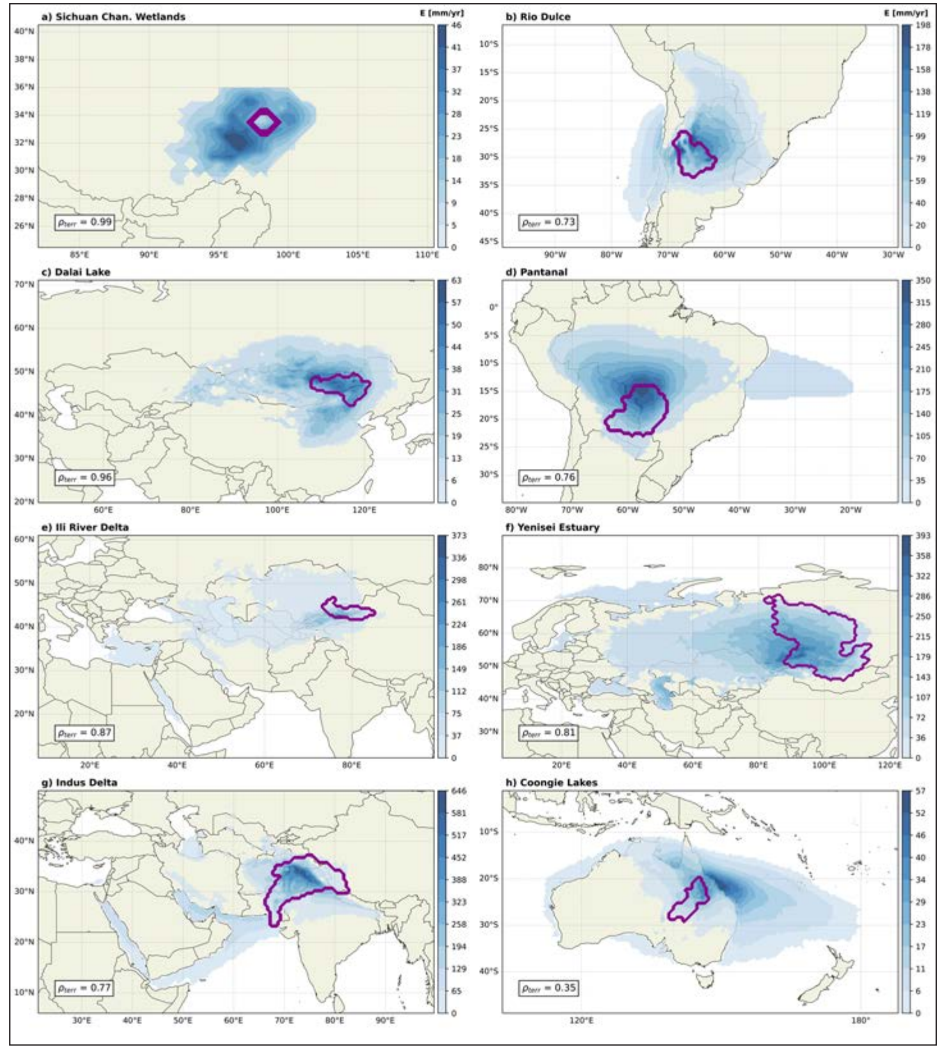
The study highlights the significant influence of remote land use changes on wetland hydrology, emphasising the need to incorporate these effects into wetland restoration, management, and conservation strategies. Recognising the role of upwind land-use changes in shaping wetland hydrologic regimes is essential for developing effective protection strategies amidst evolving environmental conditions.

Moving forward, it is imperative to conduct more in-depth studies using high-resolution time-series data to better understand the dynamics of source-to-sink moisture flows. Such research will enhance our understanding of wetland moisture recycling and its broader implications for all water-dependent ecosystems.

Fahrländer, S. F., Wang-Erlandsson, L., Pranindita, A., & Jaramillo, F. (2024). *Hydroclimatic vulnerability of wetlands to upwind land use changes*. Earth's Future, 12, e2023EF003837. *https://doi.org/10.1029/2023EF003837*



Precipitation sheds (precipitation source regions) of the 40 Ramsar wetland basins that account for 70% of their total precipitation.
Figure taken from Fahrländer et al. (2024) Figure 2.



Precipitation sheds (70% of P) of the eight identified “hotspot” wetland basins; ρ_{terr}: terrestrial precipitation recycling ratio; Figure taken from Fahrländer et al. (2024) – Supporting Information, Figure S5.

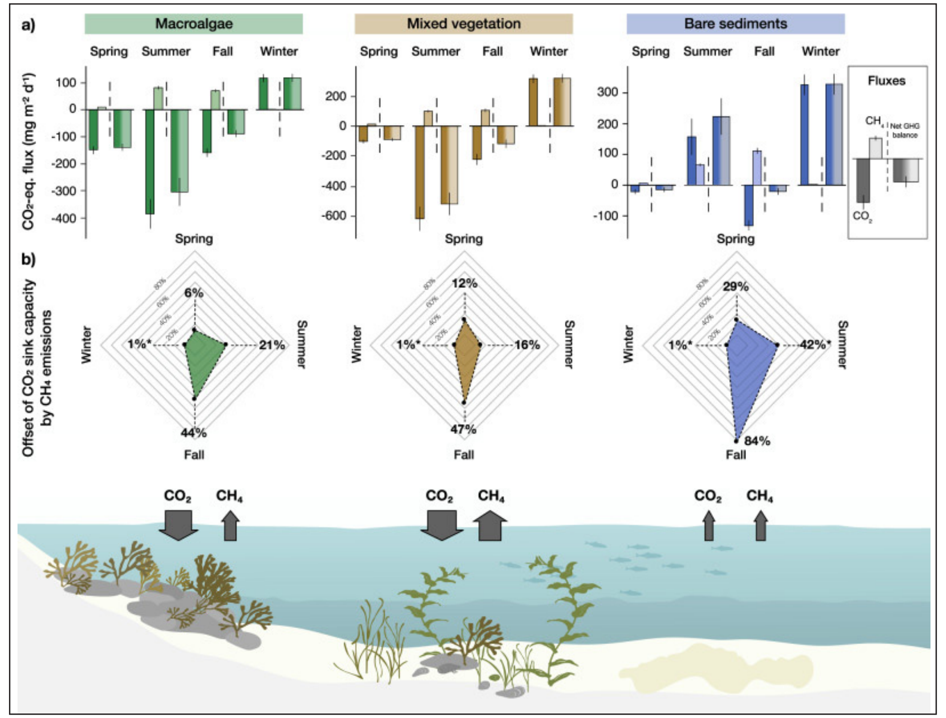
RT2 | Climate-active trace gas dynamics of CO_2, CH_4, and N_2O in coastal ocean processes

Emissions of the trace gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the coastal ocean, particularly from the shallow inshore areas, have generated strong interest regarding marine emissions. This because these coastal areas are highlighted as potential blue carbon sequestration areas, but are also among the most anthropogenically affected areas of the world thanks to human development and industrial use. RT2 has focused its research activities on a range of topics in the coastal environment by conducting local investigations in the Baltic Sea in collaboration with the Baltic Sea Centre and remote studies in the Arctic.

One of the highlights was the first-ever investigation of the shelf-wide assessment of N_2O emissions from the Siberian shelf, looking at the relationship between N_2O emissions and the land-derived discharge of nitrogen from large Russian rivers and coastal erosion in a rapidly warming region of the world, published by Wild et. al (2023). Our data shows that concentrations of dissolved nitrogen in the water and of total nitrogen in sediments increase toward large river mouths. On average, water-air N_2O fluxes were low, but strong N_2O sources and sinks were observed locally. An increase in water temperature could substantially reduce N_2O solubility in ocean water, and add to biogeochemical and physical changes. This could alter N_2O production in the shelf sediment, and convert the Siberian shelf to a N_2O source in the future.

Coastal ecosystems can efficiently remove CO_2 from the atmosphere and are therefore promoted for nature-based climate change mitigation. Natural CH_4 emissions from these ecosystems may counterbalance atmospheric CO_2 uptake. Still, knowledge of mechanisms sustaining such CH_4 emissions and their contribution to net radiative forcing remains scarce for globally prevalent macroalgae, mixed vegetation, and surrounding depositional sediment habitats. A 2023 publication by Roth et. al (2023) showed that these habitats emit CH_4 in the range of 0.1–2.9mg $CH_4 m^{-2} d^{-1}$ to the atmosphere. This was revealed by in situ CH_4 emissions from macroalgae which were sustained by conventional methanogenic archaea, but also potentially associated with photosynthetic processes. The key finding was that over an annual cycle, CO_2-equivalent CH_4 emissions offset 28% and 35% of the carbon sink capacity attributed to atmospheric CO_2 uptake in the macroalgae and mixed vegetation habitats offsetting the sink capacity of these potential blue carbon habitats. A multi-method, multi-instrument approach to tackle the complexity of trace gas emissions and carbon sequestration potential with an eye on coastal habitat diversity has risen to the forefront of RT2 investigations for the coming year.

Ocean acidification, the other CO_2 problem, continues to be a central research topic of Bolin Centre RT2 investigations, since increasing atmospheric CO_2 drives ocean acidification globally. A recent review article by Gustafsson et al. (2023) highlights that in coastal seas, acidification trends can either be counteracted or enhanced depending on management strategies, and emphasises the importance of coastal monitoring studies to accompany model-based assessments. Ecosystem effects of acidification are so far small in the Baltic Sea, but changes should be anticipated unless CO_2 emissions are curbed. Possible future acidification trends in the Baltic Sea, conditional on CO_2 emissions, climate change, and changes in productivity can be assessed by means of model simulations. There are uncertainties regarding potential consequences for marine organisms, partly because of difficulties assigning critical thresholds, but also because of knowledge gaps regarding species' capacity to adapt. Increased temporal and spatial monitoring of inorganic carbon system parameters would allow a better understanding of current acidification trends and improve capacity to predict possible future changes. An additional benefit is that such measurements also provide quantitative estimates of productivity. The technology required for precise measurements of the inorganic carbon system is readily available today. Regularly updated status evaluations of acidification, and of the inorganic carbon system in general, would support management when assessing climate change effects, eutrophication, or characteristics of the pelagic habitats. This would, however, have to be based on a spatially and temporally sufficient monitoring program.



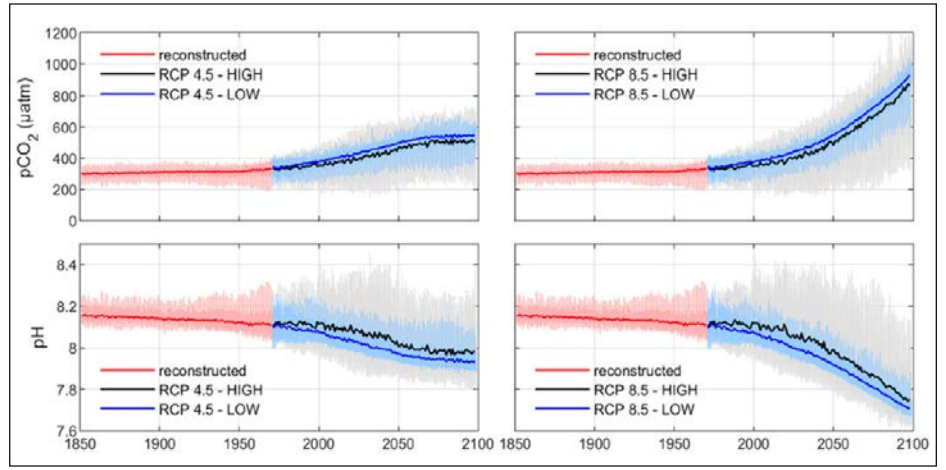
From Roth et al., (2023). Seasonal net greenhouse gas balances. Daily mean net fluxes of CO_2, CH_4, and the net greenhouse gas balance (all expressed in CO_2-eq. fluxes) (a), and the offset (in %) of the carbon sink capacity attributed to atmospheric CO_2 uptake by CO_2-eq CH_4 emissions (b). Values in a are means ± standard error. Positive fluxes refer to an efflux from the water to the atmosphere (source), while negative fluxes depict an uptake of atmospheric GHGs (sink). CO_2-equivalent CH_4 fluxes were calculated using the sustained-flux global warming potential (SGWP) on a 100-year time horizon of 4521. The net greenhouse gas balance is calculated based on net CO_2 and net CO_2-eq. Original artwork by Elsa Wikander at Azote AB.

References

Gustafsson, E., J. Carstensen, V. Fleming, B. G. Gustafsson, L. Hoikkala and G. Rehder (2023). Causes and consequences of acidification in the Baltic Sea: implications for monitoring and management. Scientific Reports 13(1): 16322.

Roth, F., E. Broman, X. Sun, S. Bonaglia, F. Nascimento, J. Prytherch, V. Brüchert, M. Lundevall Zara, M. Brunberg, M. C. Geibel, C. Humborg and A. Norkko (2023). Methane emissions offset atmospheric carbon dioxide uptake in coastal macroalgae, mixed vegetation and sediment ecosystems. Nature Communications 14(1): 42.

Wild, B., N. E. Ray, C. Lett, A. J. Davies, E. Kirillova, H. Holmstrand, E. Klevantceva, A. Osadchiev, I. Gangnus, E. Yakushev, D. Kosmach, O. Dudarev, Ö. Gustafsson, I. Semiletov and V. Brüchert (2023). Nitrous Oxide Dynamics in the Siberian Arctic Ocean and Vulnerability to Climate Change. Journal of Geophysical Research: Biogeosciences 128(5): e2022JG007326.



Gustafsson et al. (2023). Simulated surface water pCO_2 (upper panel) and pH (lower panel) in the Gotland Sea, using reconstructed forcing for the period 1851–1970 and climate change scenarios combined with nutrient load scenarios for the period 1971–2098. Thin pale lines indicate short-term variations while thick bright lines indicate annual means.

RT3 | Tracing the climatic and evolutionary history of Asian mammals: insights from dental traits and paleoclimate models

RT3 member Liping Liu and her team has explored how modern zoogeographic regions in Asia developed by examining the relationship between the dental traits of mammalian communities and climatic conditions. Using a method called redescription mining, Liu et. al (2023) have identified patterns of association between these traits and climate variables, providing insights into the history and distribution of mammal species in Asia.

Redescription mining methodology

Redescription mining is a key methodology used in this study. Redescriptions are pairs of logical statements about data variables that capture the interplay between the dental traits of mammals and their climatic conditions. Each logical statement, or query, selects a subset of localities where specific conditions are met, such as temperature or specific dental traits. The similarities between two subsets (one based on climate, the other on dental traits) is measured using the Jaccard coefficient, indicating the strength of their association.

Characterizing modern zoogeographic regions

The study identified nine significant redescriptions (patterns) that highlight the correlation between mammalian dental traits and climatic conditions across Asia, as seen in Figure 1. These redescriptions depict areas corresponding to prominent ecoregions and notable mammalian distribution patterns. This detailed characterisation helps us understand how specific regions are defined by both climate and the evolutionary traits of the mammals which inhabit them.

Emergence of modern zoogeographic patterns

Researchers traced the development of these patterns over five intervals of the Neogene period, which spans over the last 22 million years. They identified both north–south and southeast–northwest zoogeographic divisions in Asia. These patterns reflect changes in climate and tectonic activities, such as mountain ranges, which have significantly influenced the distribution and evolution of mammalian communities.

Impact of paleoclimate models

Various paleoclimate model simulations were used to understand the effect of different climate conditions on mammalian distribution. These models varied in terms of parameters like mountain elevation and climate data from different geological periods. By integrating these models, the researchers could analyse how past climate conditions impacted mammal distributions, and how these conditions have shaped current zoogeographic patterns.

Unique intergration of paleontology and climate science

One of the most interesting highlights of this study is its integration of paleontological data with climate science. The study combines data from fossil records with modern climate models, providing a comprehensive view of how mammalian communities have evolved in response to climatic changes. This interdisciplinary approach enhances our understanding of the historical context of modern zoogeographic regions.

Redescription mining as a tool

The adaptation of redescription mining, typically used in data science, to biological and environmental studies showcases its versatility in uncovering complex patterns in large datasets. This method allows researchers to identify and analyse associations between different variables, offering a powerful tool for exploring ecological and evolutionary dynamics.

Visual mapping of data

The study's results are visualised through maps, as seen in Figure 2, where different colours indicate whether the dental traits and climate conditions match the queries. This visual representation makes it easier to see the geographical distribution and overlap of these traits, providing a clear and intuitive understanding of the data.

Insights into evolutionary biology

By linking dental traits, which evolve due to dietary needs, with climate conditions, the study provides insights into how environmental factors drive evolutionary changes in species. Understanding these links helps elucidate broader patterns of evolution and adaptation in response to changing climates over millions of years.

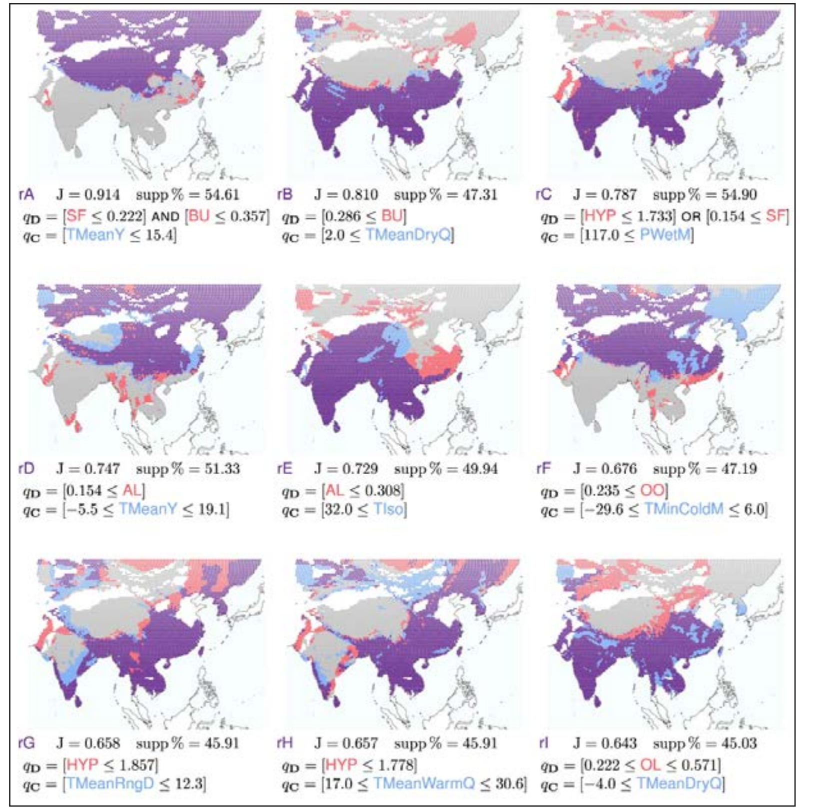


Figure 1: Redescriptions rA-rI in the present-day dataset. Localities that satisfy both queries, only the dental traits query, only the climate query, and neither query, are drawn in purple, red, blue, and gray, respectively. For each redescription, we list the query over dental traits variables (qD), the query over bioclimatic variables (qC), the accuracy (J) as well as the size of its support as a percentage of the total number of localities (supp%)."

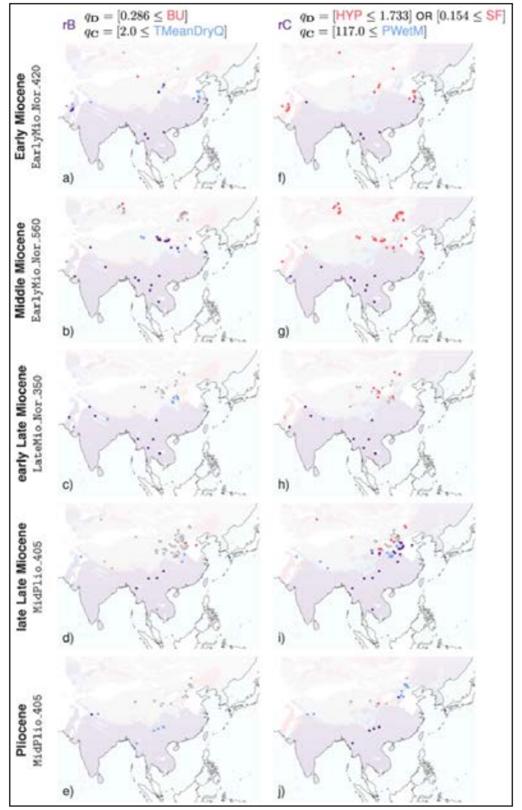


Figure 2: Focus maps of redescriptions rB and rC (columns) evaluated on fossil localities from the different time intervals, considering the corresponding paleoclimate model simulation (rows).

This study sheds light on the historical development of mammalian communities in Asia through a novel approach that links climatic conditions with evolutionary traits. The findings highlight the dynamic nature of zoogeographic regions influenced by long-term climate changes and geological events. The use of redescription mining offers a powerful tool for exploring complex ecological and evolutionary patterns, contributing valuable knowledge to both palaeontology and climate science. This integrated approach provides a richer, more detailed picture of the evolution of biodiversity in response to environmental changes, offering important insights for future research in these fields.

This text is derived from the Liping Liu et. al (2023) publication *The emergence of modern zoogeographic regions in Asia examined through climate–dental trait association patterns*, published in Nature Communications, and can be found here: *https://doi.org/10.1038/s41467-023-43807-w*

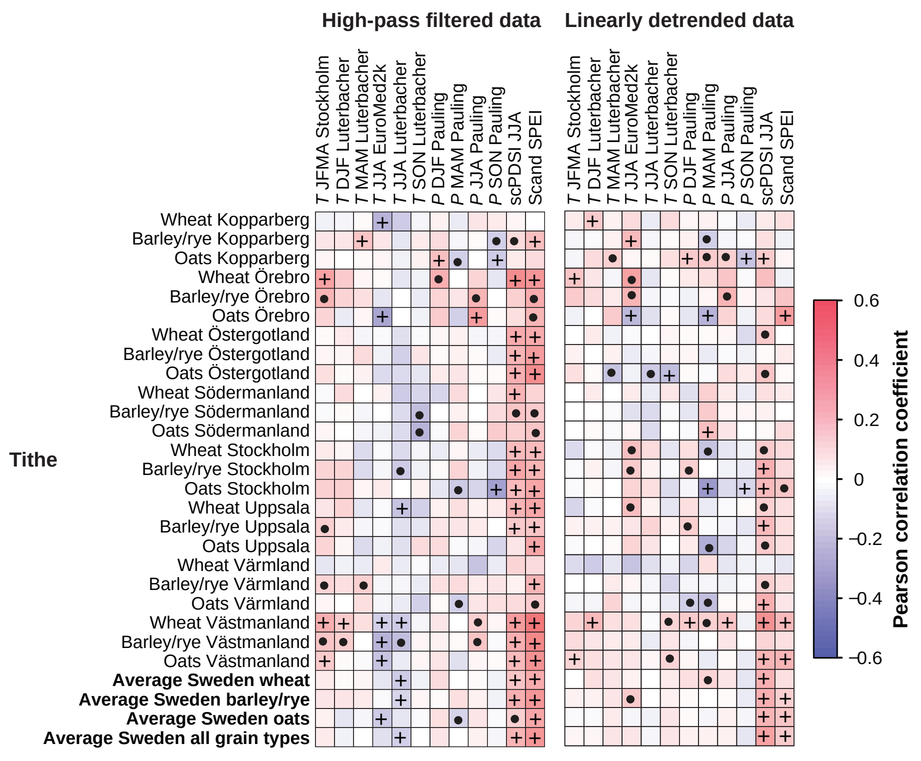
RT3 | Understanding the effects of climate variability for historical grain harvest variations throughout Europe

Despite considerable differences between historical and modern agriculture, relationships between climate variability and harvest variations of past centuries can be informative when it comes to understanding general climatic risks to crop yields. However, such studies remain rare. A team of researchers representing several disciplines studied the climate signal in long harvest series from parts of Sweden, Switzerland, and Spain from the 16th to the 18th centuries. They found regionally consistent climate–harvest relationships of similar strength and character to modern ones for the same regions and crop types.

The understanding of associations between climate variability and grain harvest variations in early modern Europe (c. 1500–1800) has long been hampered by a lack of collaboration between historians and palaeoclimatologists and by a predominant focus on extreme climate events rather than long-term relationships. A group of historians and climate researchers, with experience in working on the climate–history interface collected a large dataset of already-published data covering grain harvests from the 16th and 18th centuries in central agricultural districts of east–central Sweden, northern Switzerland, and throughout Spain. The choice of regions was motivated by data availability as well as by a wish to obtain a north–south transect across Europe. State-of-the-art palaeoclimate reconstructions of seasonal temperature, precipitation, and soil moisture, based on tree-ring data and documentary sources, were used along with several statistical techniques to investigate the relationships between climate variability and grain harvest variations for barley, rye, oats and wheat. Different methods were used to investigate climate effects on inter-annual and longer timescales.

Grain harvests in east–central Sweden were found to have benefited mainly from wetter summers, in northern Switzerland from dry and warm winters, and in Spain from cooler springs and annual mean temperatures. The strengths of these relationships are comparable to modern climate–harvest relationships at comparable spatial scales. Spain exhibited particularly heterogeneous climate–harvest relationships due to its complex topography. For the summer season in Sweden and Switzerland, the relationship between temperature and harvest was found to be timescale dependent. Warmer summers reduced harvests (presumably through droughts, sub-optimal crop development rates, and plant pathogens) on inter-annual timescales, while this adverse effect of warm summers was not detected when considering longer timescales. Longer periods with warm summers instead increased harvests, at least in Sweden. Despite the northern location, the grain harvests from east–central Sweden (around Lake Mälaren and in Östergötland) were found to be more drought sensitive than those in Switzerland or even Spain. The reason for this is partly the low precipitation in spring and early summer in east–central Sweden, coinciding with the early part of the grain growing season, and the long hours of sunshine during this season. Grain in most of Spain, with its very hot and dry summers, has a key growing season from March to May, rendering the summer drought season largely irrelevant for crop harvests.

The study revealed that the relationship between climate variability and regional harvest variations during the 16th to 18th centuries were weaker than the relationship between climate variability and grain prices during the same period. This is because grain prices, through both trade and storage, represented an average of harvests from large parts of Europe for up to several years, leading to diffused impacts of local weather on harvests. Furthermore, climate variability only explains a portion of harvest variations. This is partly because poor harvests frequently resulted from single days or weeks of unfavourable weather conditions (and not seasonal climate averages). Harvest variations were partly due to factors related to seed quantity and quality, manure availability, access to draft animals, the availability of labour, and pest outbreaks.



Swedish harvest correlations: Cross-correlation matrix for Sweden between climate series and grain tithe series at a county level for 10-year high-pass Gaussian filtered data (a) and line-arly detrended data (b), respectively. Correlations significant with a t test are marked with a dot (.).

While the strength and direction of the relationship between climate variability and grain harvest variations from the 16th to 18th centuries are surprisingly similar to those of today for the same regions and crops, the comparison between historical and modern agriculture is not without its limitations. The genetic variation of early modern grain types was much greater than it is today. Local varieties, suitable for local growth conditions, were used – particularly for barley and rye – complicating the comparisons of the relationship through time and between regions. More importantly, the longer time required to plant and harvest, and the limitations in technology used to dry the grain after harvest, posed other climatic hazards to historical grain production. Modern mechanisation, chemical fertilisers, pesticides, and higher-yielding seed varieties (which have resulted in multiplied harvest yields) have obviously changed the relationship between climate variability and grain harvest variations since pre-industrial times. Finally, while the relationships still remain similar to those of historical times, they are expected to change dramatically during the course of this century across Europe as a result of ongoing climatic warming and potential changes in precipitation patterns and their seasonality.

The study *Climatic signature in early modern European grain harvest yields* was published in the scientific journal EGU Climate of the Past on 7 December 2023: *https://doi.org/10.5194/cp-19-2463-2023*

RT4 | The consequences of climate change for agroforestry in Arabica coffee's native range

Climate change is a major threat to agriculture, both directly by affecting crop growth and yield, but also indirectly by increasing pest and disease levels. Here, we present some key findings from a cross-disciplinary project involving meteorologists, pathologists, ecologists, and social scientists focused on coffee agroforestry in Arabica coffee's native range in southwestern Ethiopia, an area that also harbours the world's only genetic reservoir of wild Arabica coffee genes.

Climate predictions

We used statistical downscaling to create predictions of the future climate of forest-covered areas in southwestern Ethiopia. To make these predictions easily accessible for stakeholders (e.g., policymakers, agricultural extension workers, and farmers), we created a visualisation tool on the Bolin Centre Database. Here, the user can select the climate model and emission scenarios, and the website shows dynamic maps, as well as the option to compare scenarios (*https://bolin.su.se/data*).

Climate-disease-yield relationships

We analysed the impact of past and present climates on disease dynamics, natural biocontrol, and yield, which allows us to learn from the past and present to predict the future. As one example, PhD student Biruk Ayalew focused on the fascinating interaction between the coffee leaf rust pathogen and its fungal hyperparasite. The fungal hyperparasite is widespread in the study area, and feeds on the coffee leaf rust pathogen. Biruk found that the coffee leaf rust pathogen and its hyperparasite differ in their climatic preferences, which suggests that there are opportunities to manage the microclimate in a way that increases natural biocontrol. A survey by a previous student at our department, Beyene Zewdie, indicated that the fungal hyperparasite controls disease levels under field conditions.

Perceptions of changes in climate and disease levels

As perceptions play an important role in adaptations to climate change, we interviewed smallholder farmers about their perceptions of changes in climate and disease levels. One interesting finding was that even though most scientific studies focus on increases in temperature, changes in precipitation and extreme weather events were at least equally important for farmers. Importantly, however, perceptions of climate change did not automatically translate into management adaptations.

Photo 1: An Arabica coffee shrub with berries. Photo: Ayco Tack

Predicting changes at the landscape-level

In an ongoing part of the project, we are focusing on how future climatic changes and smallholder farmer perceptions will jointly reshape the landscape. At high elevations, we already observed how farmers are starting coffee production above the historic elevational range for growing coffee. We are currently examining how farmers at lower and middle elevations adapt to climatic changes.

Taken together, climate-induced changes in coffee agroforestry will have major consequences for livelihoods, food security, forest cover, and biodiversity in southwestern Ethiopia.

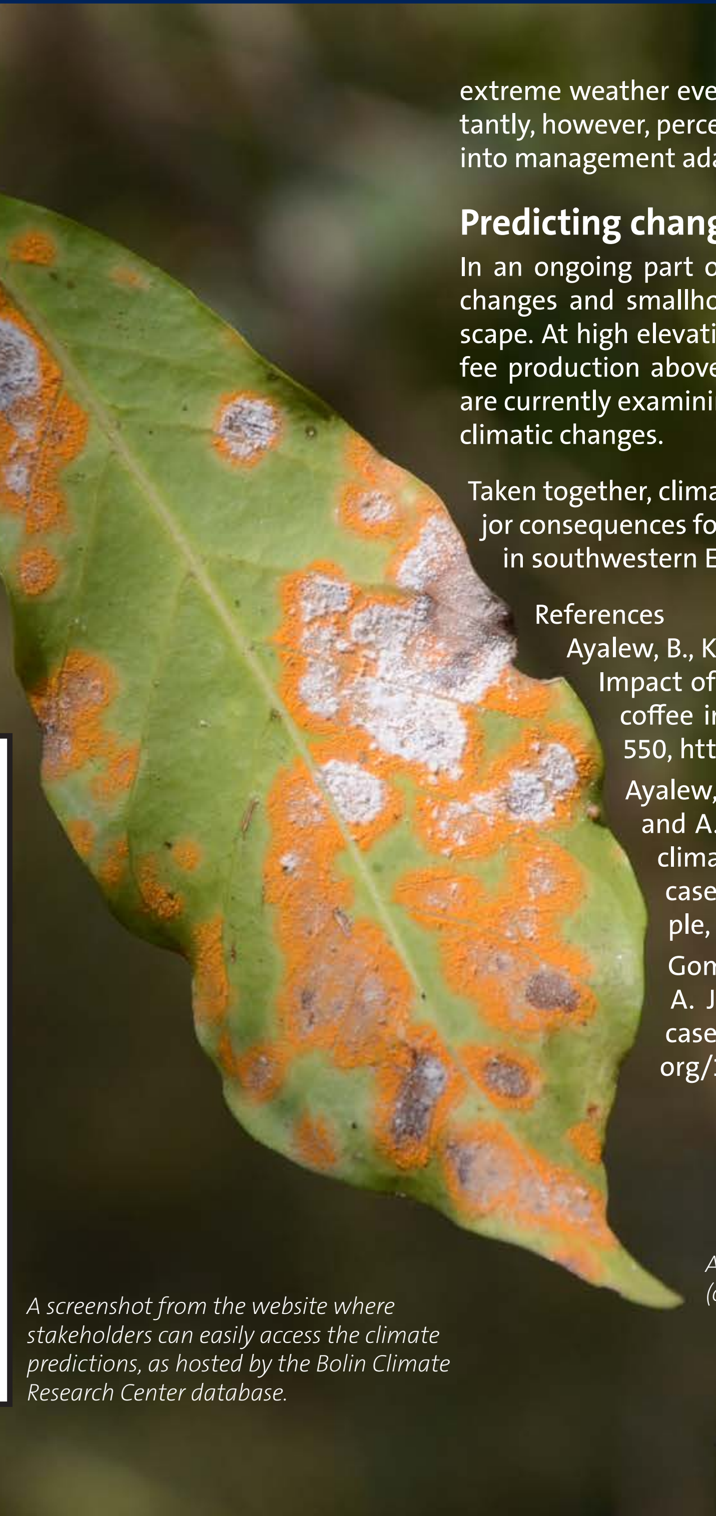
References

Ayalew, B., K. Hylander, G. Adugna, B. Zewdie and A. J. M. Tack. 2024. Impact of climate on a host-hyperparasite interaction on Arabica coffee in its native range. Journal of Applied Ecology 61: 538–550, https://doi.org/10.1111/1365-2664.14578

Ayalew, B., K. Hylander, L. Börjeson, G. Adugna, D. Beche, F. Zignol and A. J. M. Tack. 2024. Using local knowledge to reconstruct climate-mediated changes in disease dynamics and yield – a case study on Arabica coffee in its native range. Plants, People, Planet. Accepted.

Gomm, X., B. Ayalew, K. Hylander, F. Zignol, L. Börjeson and A. J. M. Tack. 2024. From climate perceptions to actions: case study on coffee farms in Ethiopia. Ambio, https://doi.org/10.1007/s13280-024-01990-0

A screenshot from the website where stakeholders can easily access the climate predictions, as hosted by the Bolin Climate Research Center database.



An Arabica coffee leaf (green) with the coffee leaf rust pathogen (orange) and its fungal hyperparasite (white). Photo: Ayco Tack

RT4 | Soil drought weakens forest microclimate cooling

An investigation led by RT4 member Caroline Greiser, researcher at the Bolin Centre for Climate Research and the Physical Geography Department looked at the mechanisms which create cool microclimates beneath forest canopies during warm and dry summer days. The study reveals the importance of soil moisture in creating cooler forest microclimates compared to temperatures outside forests.

Forests can buffer hot temperature extremes – a natural air conditioning effect. They do so by providing shade and by evaporating and transpiring water. One can imagine that forests sweat in the heat to keep their internal temperature low, and they need more water to be able to sweat. In other words, forests need soil water.

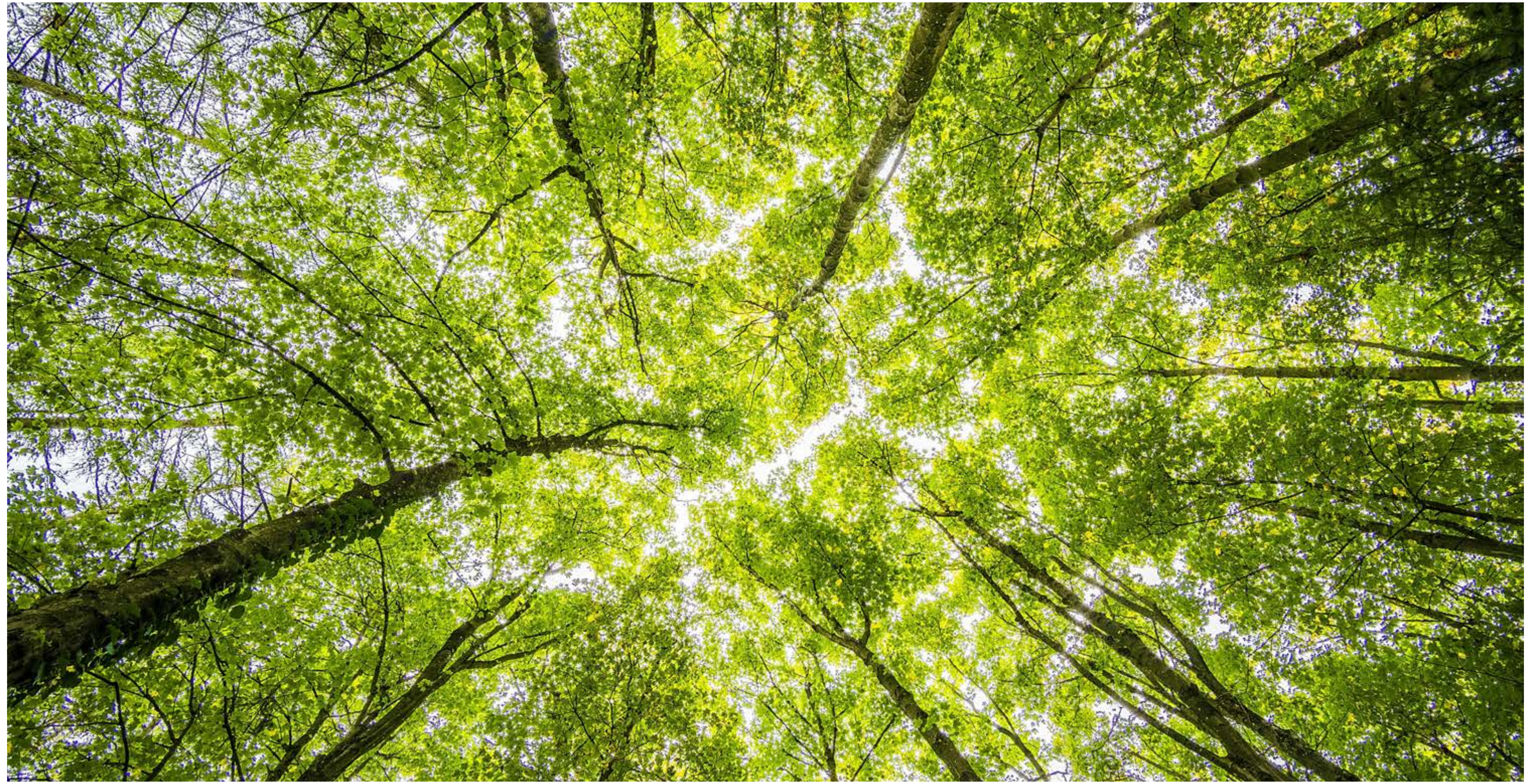
Greiser and her team explored how soil moisture variability affects temperature offsets between outside and inside the forest on a daily basis, using data from temperate broadleaf forests in Central Europe spanning four subsequent summer seasons. They found that daily maximum temperatures inside forests are, on average, 2°C cooler than temperatures outside forests. Small tree seedlings, as well as much of the forest's biodiversity, depend on these buffered forest microclimates.

Caroline Greiser, leading author of the study, in the boreal forest in Sweden, where she also studies forest microclimate with the help of small temperature and soil moisture loggers. Photo: Marian Schönauer

Drier soils create a weaker cooling effect

The research team found that higher soil moisture levels improved the cooling effect in forests, emphasising the combined contributions of canopy shade, soil water evaporation, and plant transpiration to cooler microclimates.

"We used a network of small temperature and moisture loggers spread across different forest patches to link daily fluctuations of sub-canopy temperature to canopy cover and daily fluctuations of soil moisture at a given site," says Caroline Greiser. She further adds: "Forest microclimate research often focuses on canopy cover as a major driver of understory cooling. Our study highlights the role of soil water in buffering understories from the rising heat."



Tree canopies protect the forest understory from extremely hot temperatures. Photo: FelixMmittermeier @pexels.com

As climate change causes more disturbances to forest canopies and increases the risk of soil droughts, forests may lose their cooling function. The researchers therefore emphasise the significance of incorporating soil moisture into models predicting forest microclimate, biodiversity, and tree regeneration.

"The findings are alarming in the context of climate change as more frequent and more severe droughts may threaten the cooling functions of forests," says lead author Caroline Greiser.

The study *Higher soil moisture increases microclimate temperature buffering in temperate broadleaf forests* was published in Agricultural and Forest Meteorology: *doi.org/10.1016/j.agrformet.2023.109828*

The Bolin Centre Climate Research School

The Bolin Centre Climate Research School (CRS) aims to provide a common platform for early career researchers working on climate across disciplinary boundaries and support their training to provide society with greatly needed expertise on climate.

Transformative discussion at CRS: Investigating a gender perspective in climate research

The event, *Investigating a Gender Perspective in Climate Research*, held in September 2023, provided a crucial platform for Early Career Researchers (ECRs) at the Bolin Centre for Climate Research. Participants were exposed to unique yet interconnected insights from the speakers, fostering engaging and relevant discussions. For many attendees, this event marked their first in-depth exploration of these crucial issues, emphasising the significance of re-examining familiar topics from new perspectives.

Key takeaway

Broadened Perspective: Participants appreciated the diverse perspectives offered by the speakers, finding them both enlightening and thought-provoking. This multi-dimensional approach made the content engaging and underscored its relevance. The positive feedback from attendees highlights a growing commitment to learning, raising awareness, and bridging the gap between gender perspectives in climate research.

Program highlights

Keynote Talk: *Un-culverting gendered subjects: Ecological masculinities and rights of nature as ways to mitigate and adapt to climate change*, by Associate Professor Martin Hultman, explored the gendered dimensions of the climate crisis, advocating for transformative shifts in our thinking. He introduced innovative concepts such as the rights of nature and ecological masculinities to address climate challenges.

Adapting to climate-induced changes in small-scale fisheries – Why I should have thought more about gender presented by Dr. Anna Woodhead, Postdoctoral Researcher at the Stockholm Resilience Centre and *SEA Gender: 'Look at gender in the sea' or social-ecological systems analysis and gender*, presented by Professor Maricela De la Torre Castro at the Department of Physical Geography at Stockholm University, underscored the social differentiation of climate change impacts and the pivotal role of gender, emphasising the need for realistic portrayals of social-ecological systems.

Group photo with members of the Bolin Centre CRS and ClimBEco Graduate Research School at Sörsjöns Adventure park. The excursion was part of a join side event organised during the Swedish Climate Symposium in Norrköping, 18 May 2022. Photo: Otto Hermelin

The panel discussion provided an interactive platform for engaging with the speakers on the topics presented, further enriching the dialogue.

The event's success inspired attendees, leaving them eager for more discussions at the intersection of gender and climate change. Participants departed with a renewed commitment to learning and contributing, recognising the transformative potential of their actions in effecting meaningful change.

On November 28th, the Bolin Centre Climate Research School marked the beginning of Bolin Days with a dedicated **ECR Day**. The program featured presentations on four key subjects, followed by breakout sessions aimed at a deeper exploration of each topic. Kimberly Michelle Parke, Editor and Communication Strategist at Stockholm University, offered insights into science communication and strategic planning for research projects. Ellen Bruno, Advocacy and Analysis Officer, along with Gun Rudquist, Head of Policy at the Baltic Sea Centre, discussed policy processes and the scientist's role within them. Anna Lewinschal, who coordinates support activities at the Bolin Centre, covered essential data and programming skills for climate scientists. Lastly, Prof. Kevin Noone from the Department of Environmental Science shared valuable insights on stakeholder interactions as part of the research process. Participant feedback highlighted a desire for more such activities, with many expressing interest in contributing to future events. To conclude, attendees were invited to describe their experience in three words, resulting in the creation of a word cloud reflecting their collective impressions.

Bolin Day's poster competition and exhibition

Bolin Day's poster competition and exhibition began on the day following ECR Day. Over 50 participants brought their posters to the foyer of Aula Magna, where attendees of the conference had the opportunity to interact with the authors of the posters and experience the breadth of climate science research possessed by the Bolin Centre members. The competition and exhibition continued until lunch the next day, and a jury made up of our External Science Advisory Group, together with the directors and members of the Science Advisory Group, then decided on the winners.

First place and 15,000 SEK was awarded to Sonja Gindorf for her poster *The Role of Catchment Properties for Mercury Transport and Bioaccumulation*. In second place came Jamie Barnett, with the poster *Ryder glacier in Northern Greenland: A Journey Through Time*, awarded 10,000 SEK, and in third place Caroline Greiser, with her poster *Beat the heat*, won 5,000 SEK to fund her research. Congratulations! A big thank you to the other participants who worked hard and did an impressive job with their posters – all the posters are now available on our website for all interested parties.

The Poster Competions winners. From the left: Ilona Riipinen, director of the Bolin Centre, Jamie Barnett (second place), Sonja Gindorf (first place), Caroline Greiser(third place) and Professor Jay Famiglietti member of External Science Advisory Group. Photo: Laila Islamovic

The Bolin Centre Database

– provides open access to climate and Earth system data

The database serves to promote and visualise research results and data, allowing us to highlight the stories that emerge from the data. By providing accessible and reusable literature, data, and program codes to scientists, students, journalists, and the general audience, our data repository actively contributes to the global movement towards Open Science. As such, it plays a crucial role as an integral component of the Bolin Centre.

Data management is vital in scientific research, enabling transparency, reproducibility, and reusability. At the Bolin Centre, we understand the significance of effective research data management and provide comprehensive support to our scientists. In 2023, a joint effort was initiated with the Stockholm University Library, aiming to make our Database a certified repository at CoreTrustSeal. This initiative is organised as a flagship project within the Swedish National Data Service.

Data life cycle and Open Science

Adopting an Open Science approach, the Bolin Centre recognises the importance of making scientific processes transparent. A key aspect of Open Science is ensuring that produced data is well-documented, understood, and reusable. To achieve this, we embrace the concept of the data life cycle, which encompasses various stages from planning to archiving.

Supporting the Data life cycle

Plan

Research funders often require a Data Management Plan (DMP) for funded projects. To assist researchers, Stockholm University offers centralised support and an online tool with a template for the Bolin Centre. By integrating DMP into the early stages of research planning, we ensure that data management considerations are addressed comprehensively.

Create and analyse

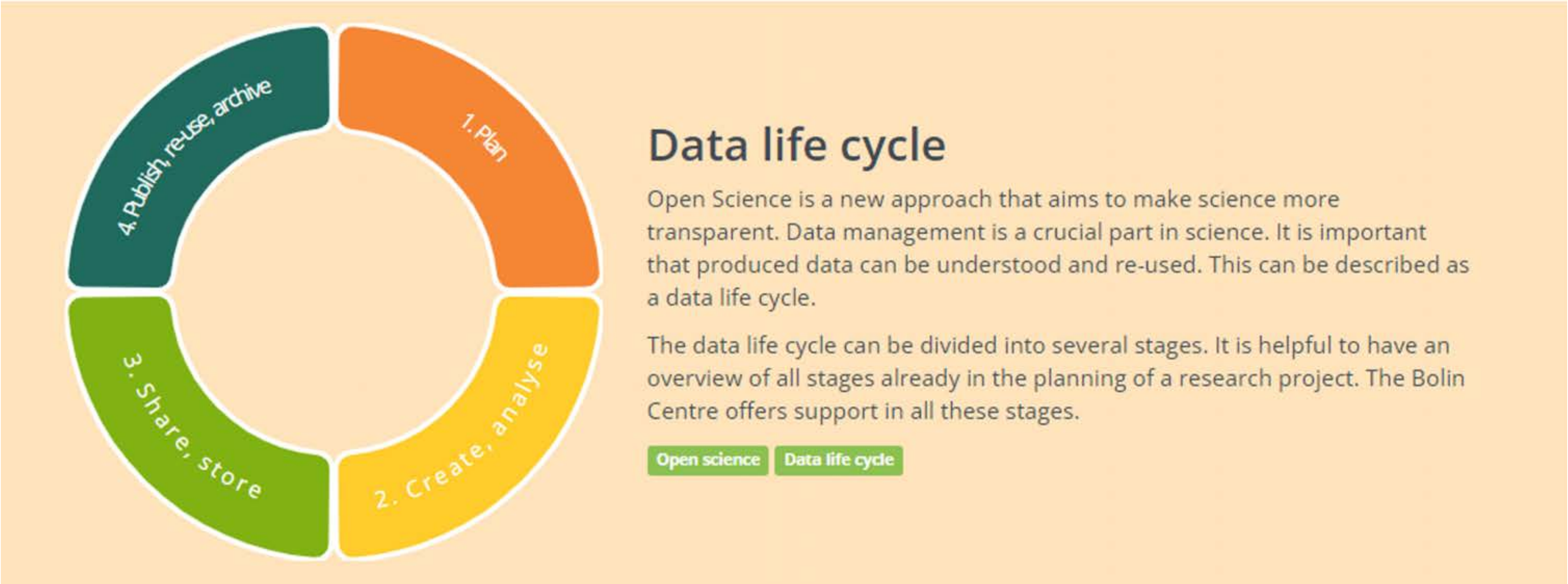
Depending on the research type, data can be generated through diverse methods. The Bolin Centre provides support for high-performance computing and storage through SNIC (Swedish National Infrastructure for Computing). This empowers our scientists by providing them with access to large-scale data resources, thereby facilitating efficient data creation and analysis.

Share and store

To promote collaboration and secure data storage, the Bolin Centre offers two general data storage alternatives. Scientists can utilise Sunet Drive and Swestore for intermediate data storage and sharing.

Publish, reuse, and archive

Journals and research funders increasingly emphasise the publication of data following the FAIR principles (Findable, Accessible, Interoperable, and Reusable) in open repositories. The Bolin Centre strongly recommends utilising the Bolin Centre Database for data publication, ensuring compliance of data with FAIR principles. Additionally, the database provides digital object identifiers (DOIs) for enhanced discoverability, integrates with Git for version control, and connects with Stockholm University's e-archive, ensuring long-term data archiving.



Effective Research Data Management is dominant in modern scientific practices. The Bolin Centre's collaboration with Bolin Centre Modelling Coordination, has resulted in comprehensive documentation and support for Research Data Management. By following the data life cycle and embracing Open Science principles, we empower our scientists to generate high-quality, transparent, and reusable data. With access to HPC resources, storage alternatives, and the Bolin Centre Database, researchers can confidently navigate the complexities of data management, enabling collaboration and innovation, and helping the researchers to make impactful scientific contributions.

Read more here: *https://bolin.su.se/data/support*

Bolin Centre Modelling Coordination

Numerical models of the global climate system are essential tools in research carried out at the Bolin Centre.
Earth system models are used across the research areas to study topics covering deep ocean circulation, land surface processes, atmospheric composition and dynamics and upper atmospheric physics. Bolin Centre researchers are also participating in the development of the next generation of Earth system models. The Modelling Coordination team at the centre ascertains that the necessary computational resources are available for the Bolin Centre researchers to be able to carry out this work.

Climate models – extensive and complex computer codes – require hardware with high capacity both in terms of computational speed and storage. High-performance computing facilities of this kind are part of the Swedish research infrastructure on the national level, and even larger facilities are available within Europe. The Bolin Centre Modelling Coordination team's primary task is to ascertain that adequate resources are available for the researchers within the Bolin Centre.

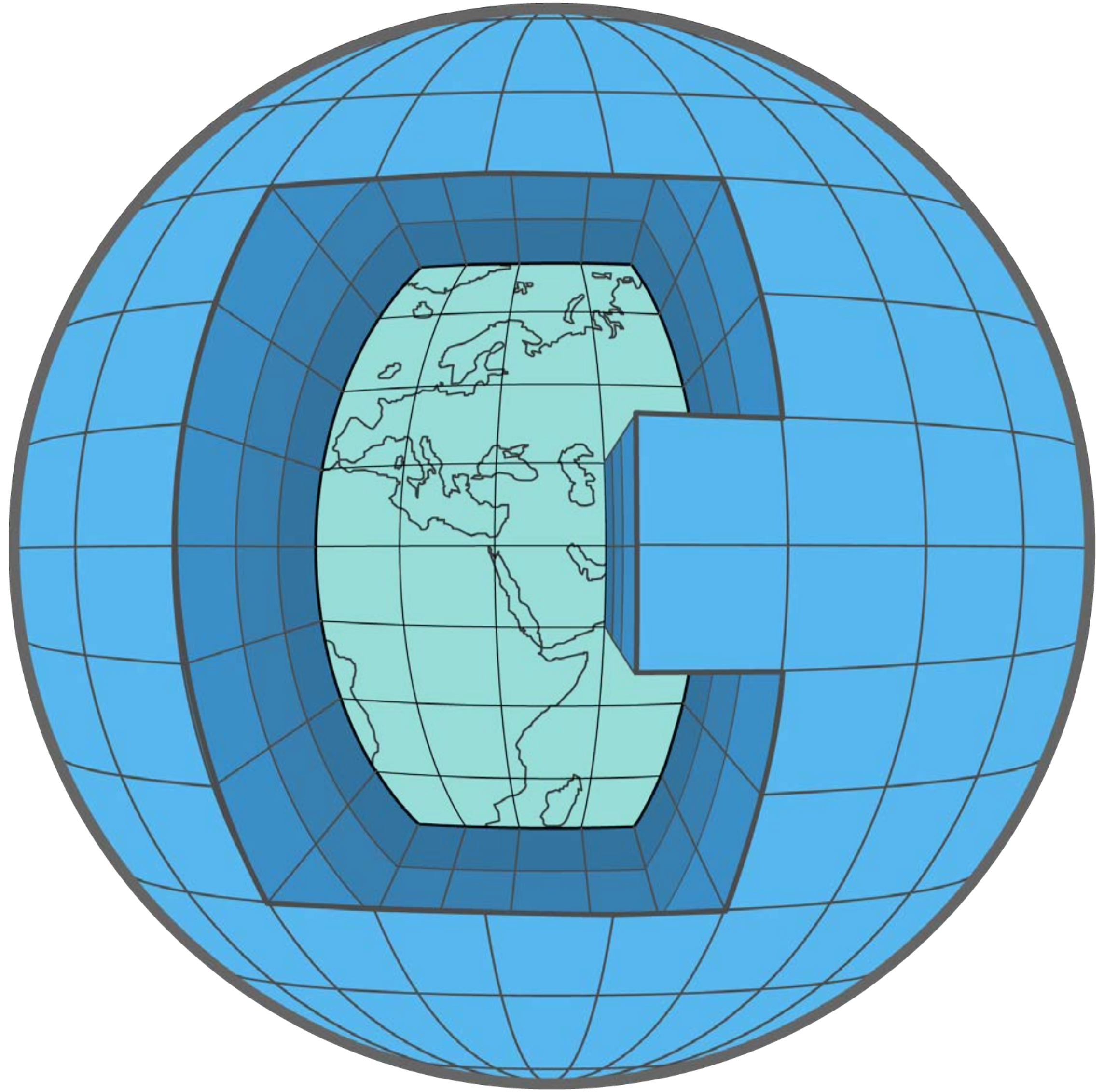
Climate models are important tools for improving our understanding of climate behaviour and the predictability of its effects on seasonal, annual, decadal, centennial and millennial time scales. The Bolin Centre uses the climate models EC-Earth and NorESM to understand how the Earth's climate varies in time and space, and how the physical and biogeochemical cycles, including human activities, interact with the climate system.

So what kind of climate modelling is performed and what has been observed? Bolin researcher Qiong Zhang and colleagues have used EC-Earth to simulate the climate response to a greening of the Sahara that happened during the mid-Holocene (6,000 years ago), and observed globe-wide climate changes such as a warmer Arctic, weakening of the climate phenomenon El Niño – Southern Oscillation (ENSO), and more tropical Atlantic cyclones. Similar modelling strategies are applied to evaluate the climate consequences of today's clean energy proposal on the deployment of massive Sahara solar farms.

Industrial activities generate not only greenhouse gases but also nano- to micrometre-sized particles in the air. These particles affect climate at the same time as they are harmful to air quality and health. A Bolin Centre team led by Annica Ekman and Hans-Christen Hansson, have used NorESM to examine how future emission paths will affect particle concentrations in the air as well as climate – in particular in the Arctic. The simulations show that future decreases in particle emissions may enhance mid-century Arctic warming by about 0.4 °C unless strong compensating reductions are made in greenhouse gas emissions.

Looking ahead, the Achilles heel of climate models is clouds since these are mostly too small to be simulated with the approximately 100 by 100-kilometre grid cells used in regular climate models. Cloud processes determine both the strength of global warming through cloud feedback, and the character of climate change such as precipitation extremes and droughts. With the increasing computational power available an international team led by Thorsten Mauritsen is working to bring the next-generation ICON (Icosahedral Nonhydrostatic) climate model to a new supercomputer named LUMI that is being built in Finland. They hope to be able to run with a global grid of one by one kilometres, permitting most clouds to be simulated.

Bolin Centre researchers also use more detailed models than climate models to better understand different processes and interactions within the climate system, for example models covering only a column of the atmosphere and ocean, ice sheet models, hydrological models, and large eddy simulation.



*A climate model is a three-dimensional representation of the atmosphere that is coupled with the Earth's surface and the seas.
In short, the atmosphere and the seas are divided into a series of boxes, or grid cells. In each cell of the grid, values of the temperature, humidity, air pressure, wind speed, sea ice and vegetation are calculated. After the climate's condition in each cell has been calculated, a step forward in time is taken, and all values are calculated again.
Illustration: SMHI*

Communication and coordination

The Communication and Coordination Team at the Bolin Centre works to facilitate effective communication and coordination throughout the organisation. Their responsibilities include creating content for diverse channels, organising outreach events, and coordinating both internal and external meetings and gatherings, such as the Annual Bert Bolin Climate Lecture and Bolin Days. Additionally, they manage and produce engaging content for the Bolin Centre website, along with providing regular newsletters to its members.

Bolin Centre is bridging the gap between Climate Science and Policy

The panel discussion held on May 23, 2023 highlighted the importance of enhancing communication and collaboration between scientists and policymakers. It emphasised the need for policymakers to actively engage with climate science and research to make informed decisions. Building trust, managing expectations, and demonstrating effective leadership were identified as crucial elements in policy-making.

Panellists stressed the need for a more structured approach, including increased involvement of scientists in policy discussions. They emphasised the benefits of diverse perspectives and the importance of personal exposure between scientists and policymakers.

The discussion underscored the intensive and sometimes challenging process of reaching agreements between scientists and politicians. Effective communication, collaboration, and shared responsibility were identified as key factors in achieving meaningful outcomes.

The panel discussion provided valuable insights into the challenges and opportunities in bridging the gap between climate science and policy. It emphasised the importance of effective communication, diverse perspectives, providing good examples, and collaborative efforts in driving positive change.

The Bolin Centre sees its important role in keeping up this dialogue and will continue organising similar events in the future.

Bolin Centre inspires high school students in climate research at ForskarFredag 2023

The Bolin Centre for Climate Research participated in ForskarFredag 2023 in Stockholm on September 29, 2023, when 11 Bolin researchers engaged high school students with interactive exhibits aimed at deepening their understanding of climate science. The event showcased the Centre's commitment to inspiring and educating the next generation on climate complexities.

Visitors were offered the following experiments and demonstrations

Cloud in a bottle: Demonstrating cloud formation and particle dynamics, highlighting weather's influence on climate.

ForskarFredag in Albanova. Photo: Maria Basova

Satellite imagery and environmental monitoring: Showcasing the power of satellite imagery in environmental research, emphasising the interconnectedness of climate, water, and ecosystem health.

Tree rings – Nature's historical record: Providing insights into climate history through tree rings, showcasing the resilience and challenges imprinted within them.

Exploring climate impact on biodiversity: Offering hands-on experiences in scientific research, demonstrating the relationship between climate change and biodiversity.

By offering engaging exhibits and interactive experiences, the Bolin Centre aimed to foster a deep interest in climate research among young minds, aligning with its mission to make climate science accessible and inspiring.

The Bolin Days 2023

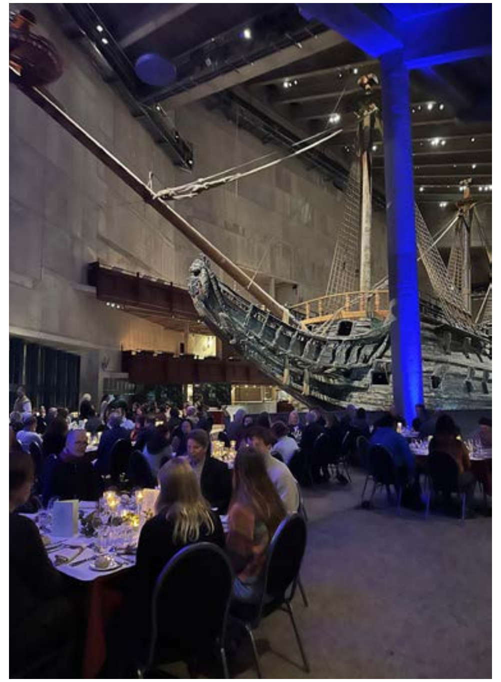
The 15th edition of the Bolin Day's brought together over 200 members, who shared their research and knowledge, opening up for new opportunities and collaborations. The conference started off with a day dedicated to Early Career Researchers; the ECR Day. The day consisted of presentations on four subjects: science communication, policy processes, essential data and programming skills, as well as interactions with stakeholders as part of the research process. The consensus among the participants seems to be that more of these types of activities are much needed and appreciated.

Programme and reflections

The Bolin Day's programme was divided into six different sessions over two days in Aula Magna at Stockholm University. Four out of the six sessions reflected the four research themes within the centre (page 12), and during the other two sessions we had the pleasure to hear from external collaborative partners, such as Science Officer Daniel Ospina from Future Earth, giving us an overview of the report *10 New Insights in Climate Science*, that highlights key messages from researchers to policy makers. Magnus Breitholtz from the Dept. of Environmental Science introduced the last day of the conference talking about the University Alliance Stockholm Trio for Sustainable Actions.

The programme concluded with the announcement of the winners of the poster competition, which was held throughout the conference. After careful deliberation, the jury – comprising members of the External Science Advisory Group, along with directors and members of the Science Advisory Group – decided to award Sonja Gindorf, Jamie Barnett, and Caroline Greiser for their posters. (Read more about the poster competition on page 31.)

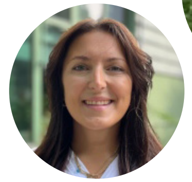
A conference dinner at the Vasa Museum concluded this year's Bolin Days; members got a guided tour and some delicious food with a spectacular view.



Conference dinner at Vasa Museum to wrap up the Bolin Days 2023. Photo: Laila Islamovic

Maria Basova joined the Bolin Centre in September 2022 as coordinator. Photo: Uly Konstantinow

Sara Gershagen continued as a part-time coordinator until April 2023. Photo: Luliana Domina



Laila Islamovic joined the Bolin Centre in September 2023. Photo: Maria Basova

The Bert Bolin Climate Lecture

Professor Bert Bolin was not only a leader in climate research, but also one of the founders of the IPCC, which received the Nobel Peace Prize in 2007. To commemorate his contributions, the Faculty of Science at Stockholm University established the annual Bert Bolin Climate Lecture.

Every year, the Faculty of Science selects a prominent scientist in the field of climate research to give the lecture, which is held at Stockholm University. The Bolin Climate Lecturer is appointed by the Dean of the Faculty of Science, and nominations can be made by all Bolin Centre members in response to a call. The lecture provides an opportunity for the distinguished scientist to give both a popular science lecture and a science seminar, sharing their knowledge and insights with the wider community.

In 2023, the honourable speaker was Professor Trude Storelvmo, who gave the 15th Bert Bolin Climate Lecture on May 24, 2023.

The lecture was entitled: ***The Big Unknown in Future Climate Projections.***

As a climate scientist, Professor Storelvmo has studied the role of aerosol particles and clouds in Earth's climate, focusing on cloud–climate feedback mechanisms, climate engineering, and the Earth's climate sensitivity. Her research group uses a variety of research tools, including Earth System Models, Satellite Remote Sensing, laboratory experiments, aircraft measurements, and ground-based remote sensing.

Professor Storelvmo has also made significant contributions to IPCC's 5th and 6th Assessment Reports, serving as a contributing author for Chapter 7 in the former and a coordinating lead author for Chapter 7 in the latter. She is also a member of the International Commission on Clouds and Precipitation.

In her lecture, Professor Storelvmo captivated the audience with some interesting ideas about how microscale cloud physics can affect the big picture of climate change. She discussed the interactions between cloud droplets and ice crystals within mixed-phase clouds and how these interactions can either accelerate or decelerate global warming, depending on factors such as greenhouse gas levels. Her presentation shed light on the crucial role of these small-scale cloud processes in our understanding of climate dynamics. She emphasised that as the planet continues to warm, these cloud interactions could become increasingly influential in shaping our climate. Overall, Professor Storelvmo's talk underscored the importance of studying clouds to effectively address climate change. Additionally, some key points from her presentation included an examination of the global climate context, outlining our current position and future trajectory, highlighting clouds as a significant source of uncertainty in future climate projections, exploring the substantial impact of micro-scale cloud processes on future climate scenarios, and discussing the potential existence of climate tipping points involving clouds.

Professor Storelvmo with a research team in front if of the plane. Photo: Terje Megård

Further insights shared during the presentation included that clouds cover approximately 60%–70% of our planet's surface, playing a critical role in regulating its temperature. Even minor fluctuations in cloud cover can have a profound impact on global temperatures. Clouds are integral to global climate models due to their role in climate feedback mechanisms, and cloud feedback remains one of the most uncertain factors in climate modelling, with changes in cloud altitude, amount, and optical thickness contributing to this uncertainty.

In her summary, Professor Storelvmo emphasised that global warming is rapidly approaching the 1.5°C temperature target set in the Paris Agreement. Every additional degree of warming increases the risk of heatwaves and extreme precipitation. The future climate largely depends on our ability to cut greenhouse gas emissions. However, there are significant uncertainties in the temperature outcome for a given emission pathway, largely due to uncertain cloud feedback. Negative feedback related to the conversion of cloud ice to liquid currently reduces warming, but this effect has been overestimated. Potential tipping points involving clouds have been proposed, but the evidence so far suggests that these would only materialise at very high levels of warming.

Let's do our best to avoid reaching those levels!

Lecturers

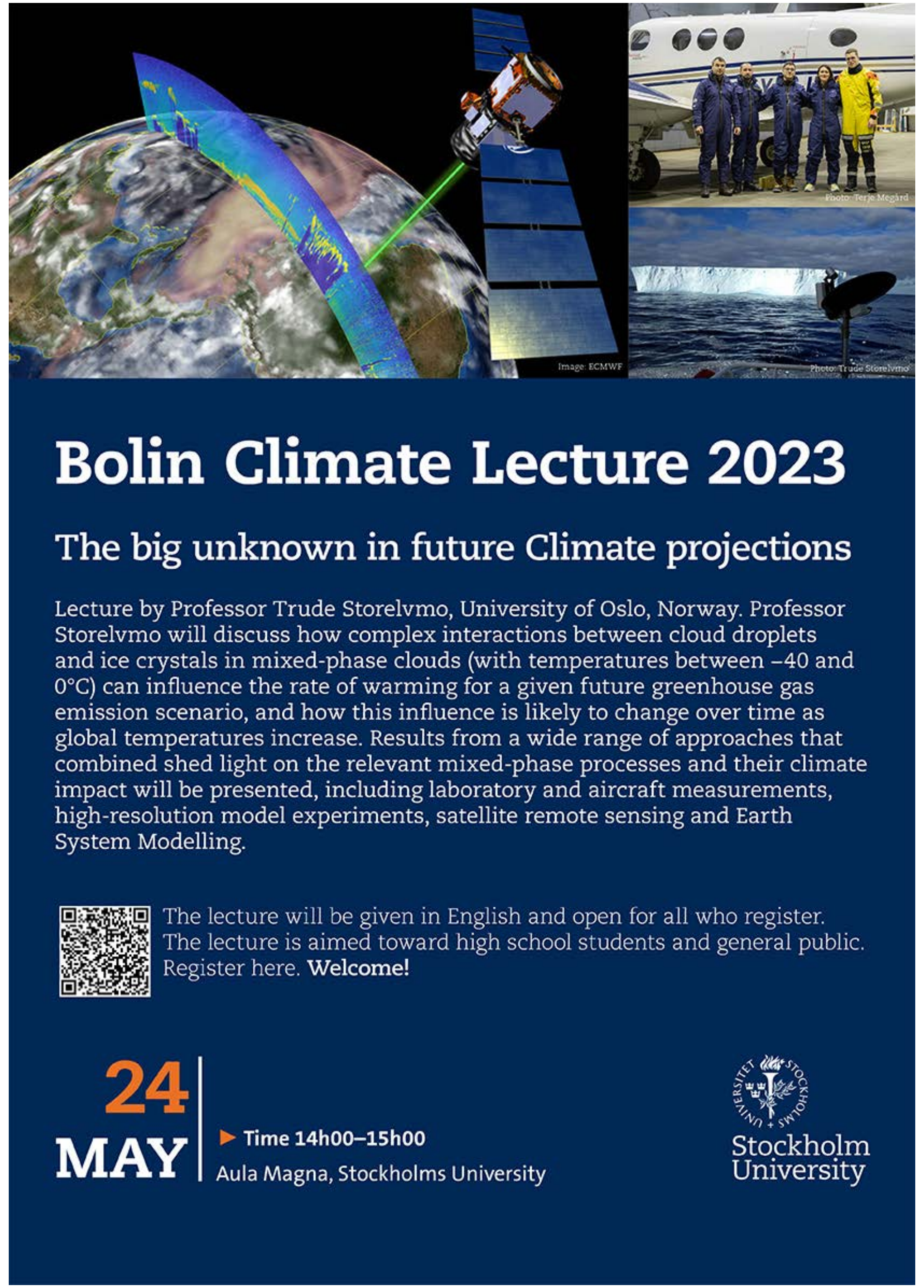
2023 | Professor Trude Storelvmo
The big unknown in future Climate projections

2022 | Professor Hans Joosten
The Great Rewetting: Why we must stop draining peatlands – Worldwide and as fast as possible

2021 | Professor Emeritus William F Ruddiman
For how long have humans affected the climate?

2020 | Professor Roberto Buizza
Climate Change: How can we motivate transformation?

For a clomplet list of all the Bert Bolin Climate Lecturers please visit:
www.bolin.su.se/Research/Conferences and seminars



The Bolin Centre Board

The Bolin Centre is led by the Bolin Centre Board, which comprises representatives from all of its collaborative partners: six departments at Stockholm University, the Swedish Meteorological and Hydrological Institute, and KTH Royal Institute of Technology. In addition, the board includes an external member and a student representative.

Professor Martin Jakobsson
Chair of the Bolin Centre board, Department of Geological Sciences, Stockholm University.

Professor Johan Nilsson
Vice-Chair of the Bolin Centre Board, Department of Meteorology, Stockholm University.

Professor Anna Sobek
Department of Environmental Science, Stockholm University.

Professor Rodrigo Caballero
Department of Meteorology, Stockholm University.

Professor Sara Cousins
Department of Physical Geography, Stockholm University.

Professor Kristoffer Hylander
Department of Ecology, Environment and Plant Sciences, Stockholm University.

Professor Bengt Karlsson
Department of Zoology, Stockholm University.

Professor Carl-Magnus Mörth
Department of Geological Sciences, Stockholm University.

Professor Fredrik Lundell
Teknisk Mekanik, KTH – Royal Institute of Technology.

Ralf Döscher, PhD
Head of the Rossby Centre at SMHI – the Swedish Meteorological and Hydrological Institute.

Aaron Tuckey
Climate Objectives Unit, Swedish Environmental Protection Agency.

Jonathan Wiskandt, PhD student
Department of Meteorology, Stockholm University.

Professor Ilona Riipinen
Ex Officio, Director of the Bolin Centre, Stockholm University.

Professor Gustaf Hugelius
Ex Officio, Vice-Director at the Bolin Centre, Stockholm University.

Maria Basova
Ex Officio, Coordinator at the Bolin Centre, Stockholm University.

Laila Islamovic
Ex Officio, Communicator at the Bolin Centre, Stockholm University.

Please note that the list of Board members is accurate as of December 2023.
Later changes to the Board membership may have occurred.
The most up-to-date information is available on our website,
www.su.se/bolin-centre-for-climate-research/about-the-centre/organisation

The External Science Advisory Group

The Bolin Centre has appointed an ESAG composed of leading national and international scientists working within climate research. The group's main tasks are to inform the Bolin Centre of its strengths, weaknesses, and possibilities for development, as well as to increase the Bolin Centre's contacts with international networks and research groups within the climate research area.

Professor Jay Famiglietti

(Chair) Arizona State University, School of Sustainability, College of Global Futures.

Professor Karen E. Kohfeld

Director and Professor, School of Environmental Science Professor, School of Resource and Environmental Management Simon Fraser University, Burnaby, Canada.

Professor Camille Parmesan

National Aquarium Chair in the Public Understanding of Oceans and Human Health at the University of Plymouth U.K., at SETE – Theoretical and Experimental Ecology Station, CNRS *Centre National de la Recherche Scientifique*, France and adjunct professor at The University of Texas at Austin, U.S.A.

Professor Victor Brovkin

Max-Planck-Institute for Meteorology, Department of Climate Dynamics.

Professor Trude Storelvmo

University of Oslo, Dept. of Geosciences, Section for Meteorology and Oceanography.

Please note that the list of ESAG members is accurate as of December 2023. Later changes to the ESAG membership may have occurred.
The most up-to-date information can be found on our website: *www.su.se/bolin-centre-for-climate-research/about-the-centre/organisation*

Photo: Inês Jakobsson

Bert Bolin – a world-leading scientist and science organiser

Bert Bolin joined the newly created Department of Meteorology at [1]Stockholm University in 1948 as an assistant to Professor Carl-Gustaf Rossby. Apart from a few brief absences, Bert Bolin remained an active member of the department staff until his death in 2007.

During a productive period as Rossby's student he wrote several fundamental papers on atmospheric circulation and on the basic principles for numerical weather prediction. After he received his PhD in 1956, he broadened his interests to include studies of biogeochemical cycles of key life elements. This became the introduction to his world-leading research on the carbon cycle in the atmosphere, oceans and biosphere.

Bert Bolin was not only a prominent scientist; his role as an inspirer and organiser of international climate research has been of outstanding importance. Due to his broad and deep scientific knowledge, his unusual ability to see the big picture, his eminent ability to express himself orally and in writing, and his diplomatic talent, he became a natural leader. He initiated several research programmes focusing on the global environment including the World Climate Research Programme and the International Geosphere-Biosphere Programme.

Bert Bolin's most important achievement was his contribution to the formation and development of the Intergovernmental Panel on Climate Change (IPCC) under the UN. He chaired this panel during its first ten years (1988–1997). His extremely important role as the founder and initial leader of the IPCC has been confirmed by many. The IPCC received the Nobel Peace Prize in 2007.

[1]Stockholm University was formed in 1960 from Stockholms Högskola, which was founded in 1878.

The legacy of Bert Bolin remains alive among climate scientists at Stockholm University and at many other places through the inspiration that he brought with lectures, supervision, his scientific approach and his commitment to making research results available to policy makers and the public.

Henning Rodhe
Bert Bolin's student, colleague and friend

You can watch a slide show about Bert Bolin and the Bolin Centre for Climate Research at https://www.su.se/english/about-the-university/cultural-heritage-and-history/the-history-of-stockholm-university/bert-bolin-founder-of-the-climate-panel-and-world-leading-scientist-1.531330.

Photo: Malin Kylander

Bolin Centre for Climate Research

The Bolin Centre is a multi-disciplinary consortium of more than 400 scientists in Sweden who conduct research and graduate education related to the Earth´s climate. It was formed in 2006 by Stockholm University, and in 2010 the KTH Royal Institute of Technology and the Swedish Meteorological and Hydrological Institute joined the centre.

The Bolin Centre focuses on extending and disseminating knowledge about the Earth's natural climate system, climate variations, climate impacting processes, climate modelling, human impact on the climate and climate impacts on ecosystems, biodiversity and human conditions as well as how society can minimise negative impacts through responsible management.

The Bolin Centre for Climate Research is named in honour of Professor Bert Bolin of Stockholm University, a leader in climate and carbon cycle research and one of the founders of the Intergovernmental Panel on Climate Change (IPCC), which received the Nobel Peace Prize in 2007.

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