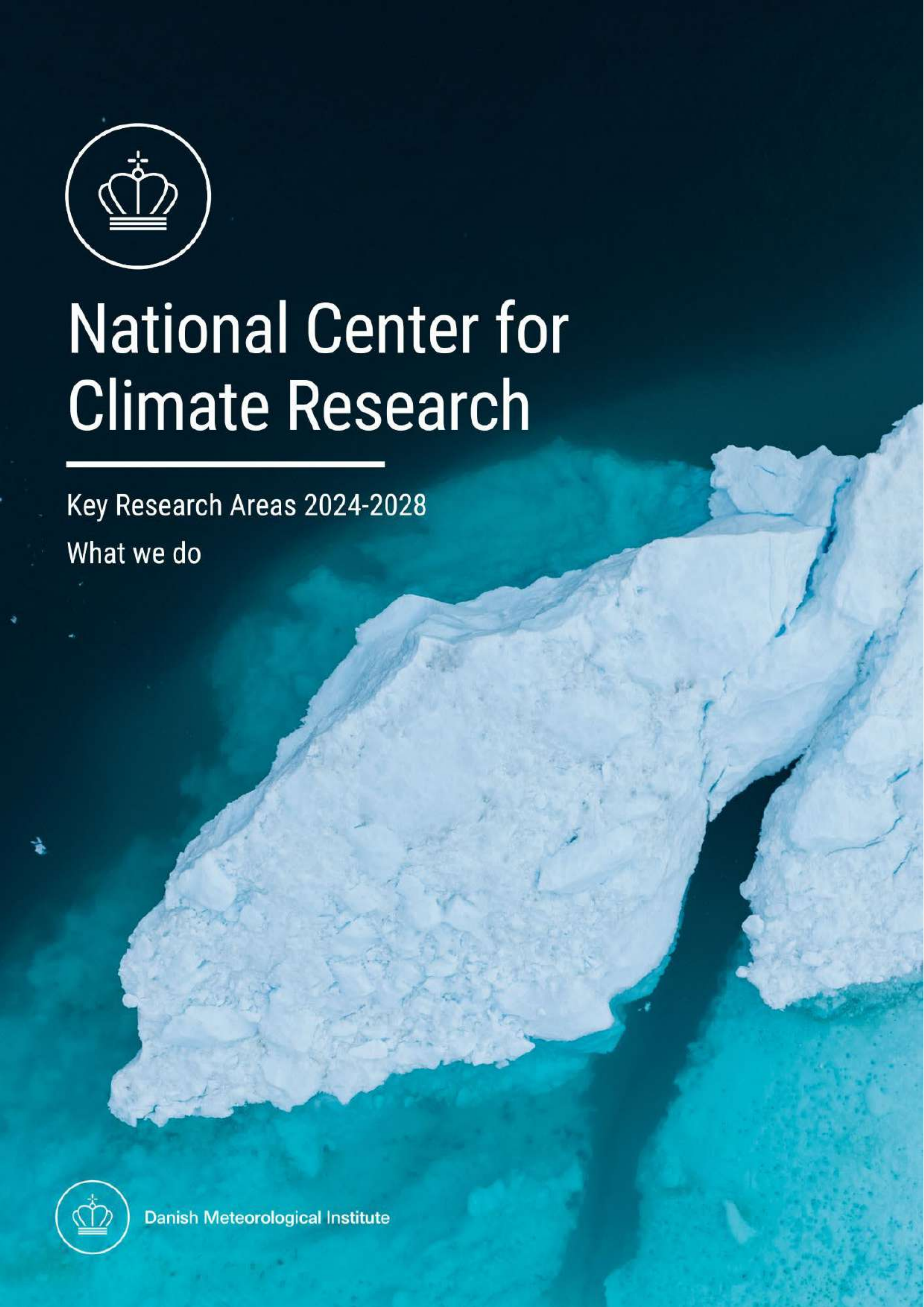

National Center for Climate Research

Key Research Areas 2024-2028

What we do

Danish Meteorological Institute

INTRODUCTION

As the National Center for Climate Research at DMI we are proud to be Denmark's climate scientific advisor. We aim to achieve global climate insight and apply our knowledge to create local, societal value.

Through monitoring, modelling, and analysis, we conduct impactful research and development. We deliver authoritative scientific knowledge and data related to both long-term climate scenarios for planning and decision making, while also providing data for operational needs and practical purposes.

We have a strategic direction of our research: We prioritize key research areas that are particularly relevant for the society in Denmark – and in and around Greenland and Faroe Islands – aiming to advance the understanding of the climate system and the challenges we face in a warming world.

We operate with a multi-year research framework. While priorities and detailed scientific directions are regularly updated, we have identified a number of key research areas. The key research areas will guide our work and ensure progress and allow for a contribution to the global climate scientific frontier.

Our key research areas are in support of our strategy for the period 2024-2028, "*Global insight, local value*".





Top left:
Ole Krarup Leth
Jacob Høyer
Rasmus Anker Pedersen
Christina Hoff Jensen
Adrian Lema

WHAT WE DO

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SUMMARY OF STRATEGY

2024-2028

VISION

World-class in climate science, world-class in supporting society

MISSION

The mission of NCKF is to carry out relevant high-quality and impactful applied climate research which through monitoring, modelling, and analysis provide knowledge and data that is effectively communicated in support of informed decision-making and creates value for society

STRATEGIC OBJECTIVES

- Higher research impact
- A stronger national climate science advisor
- Support societal climate transformation
- Stronger use of cutting-edge technology and more robust IT-support
- A more effective and dynamic organization

KEY RESEARCH AREAS

2024-2028

FUTURE EXTREME WEATHER AND SOCIETAL RESILIENCE	• Extreme weather in Denmark and attribution to climate change • Climate Services, monitoring, and impacts of climate change • The green transition and greenhouse gas emission mapping
POLAR CLIMATE CHANGE AND IMPACTS	• Ice sheet retreat and the changing climate in Greenland and Antarctica • Sea level rise – sources and impacts • Sea ice decline, polar amplification, and maritime safety
GLOBAL WARMING AND TIPPING POINTS	• Global atmospheric dynamics and European weather patterns • Ocean predictability – variability and long term change • Risks and impacts of climate tipping points

SCIENTIFIC APPROACHES

Climate modelling

Monitoring

Statistics and analyses

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Future extreme weather and societal resilience

Extreme weather in Denmark and attribution to climate change

Heat records are broken frequently; what was once rare precipitation and storm surge events now become more and more frequent. A future warmer climate will have many days that appears unchanged from today – but the changing extremes will challenge our societies, not least when multiple concurrent extremes and compound events challenge our adaptation and emergency preparedness. Attribution studies can reveal how natural weather variability and climate change combine into more frequent heat waves, droughts, storm surges, cloudbursts, persistent winter rains, and floods. Climate models are central in studying the changing processes in a warming climate, while observations document ongoing changes, e.g., warming trends, and connect extreme weather to its impacts, e.g., by mapping droughts and floods from satellite. Long term monitoring and forecast systems can further provide impactful information about current extremes.

Climate Services, monitoring, and impacts of climate change

Development of climate services is needed to bridge the gap between scientific data and societal decision-making. NCKF has developed *Klimaatlas*, which supports climate adaptation planning across Denmark. This expertise can be utilized in several other aspects; both in other sectors in Denmark and in international networks and collaborations. Supporting climate services also entails contributing to international programs that collect and distribute observational data. The decisions and work behind climate services require experience and expertise in data management and statistical analyses combined with stakeholder-dialogue, communication, and visual presentation techniques. Observational data, predictions, and projections – whether it is on ocean and atmospheric changes, sea ice, emission monitoring or the future extreme precipitation in Denmark – can provide a direct value when efforts are made to tailor climate services to societal needs. Mapping concrete impacts of climate change is an example of tailored climate information. Operational services to enhance security and safety for people, nature and infrastructure is another way to create direct value.

The green transition and greenhouse gas emission mapping

Cost effective transition to a green and sustainable society increasingly requires knowledge on emission reductions, effects and inventories. Forecasts and observations can serve as input to optimization of renewable energy production and can be used to validate inventories as well as distinguishing between anthropogenic and natural emissions. Although this is a novel addition to NCKF’s research portfolio, vast experience with satellite observations, detailed model-based predictions, and calculations serves as a foundation for expanding this further. Additionally, NCKF’s IPCC focal point role can be utilized to align research and reporting with required standards.

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Polar climate change and impacts

Ice sheet retreat and the changing climate in Greenland and Antarctica
The climate in the Polar Regions is changing and the big ice sheets in Greenland and Antarctica are losing mass at an increasing pace, and will continue to do so for many years ahead. Monitoring, modelling, and assessment of the climatic conditions on and around the ice sheets are key to understand climatic changes and assess the mass balance. Current efforts document the ongoing change and raise concerns for the future, as the two ice sheets have potential to raise the sea level by several meters in the coming centuries. The global impacts stress the need for both detailed monitoring, model projections, and efforts to improve our process understanding of the melting ice sheets.

Sea level rise – sources and impacts
Regardless of the future emission of greenhouse gases, the sea level will continue to rise for many years. From a global perspective, where a substantial part of the population lives in coastal areas, to our own low-lying country with a long coastline, climate adaptation will be needed. Understanding the interplay between increasing temperature, ice sheet melt, global sea level variability and the storm surges that threaten the Danish shores is key to provide the best foundation to keep our society resilient in the coming changes.

Sea ice decline, polar amplification, and maritime safety
One of the most palpable signals of the ongoing climate change is the rapid loss of sea ice, which is also contributing to the amplified warming in Polar Regions; especially the Arctic. The loss of the reflective and insulating snow and sea ice layer on the ocean surface accelerates the ongoing warming and brings substantial changes to the Polar Regions – and beyond. More accessible polar oceans, both in the Arctic and the Antarctic, increase the need for detailed monitoring and operational mapping, modelling, and forecasting of the sea ice (extent, thickness, drift, snow, etc.) and the ocean beneath. This also includes modelling and information to support mariners and the Greenlandic community. Long term monitoring and forecasting can help communities in addressing hazardous events. It also create the foundation for the validation of long term prediction systems. Further, ongoing and future changes in the sea ice cover

drive large-scale atmospheric and oceanic changes which motivate both regional and global climate model analyses.

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Global warming and tipping points

Global atmospheric dynamics and European weather patterns

Along with the rising sea level, the changing atmospheric dynamics shape how we will experience the changing climate. Weather patterns change, extreme heat increases, and warm air holds more moisture thereby increasing extreme precipitation in Denmark, Europe, and globally. Changes in the atmosphere are interlinked from the surface to the stratosphere, requiring both an overview of the current and past state and an understanding of how changes interact. Detailed model-based predictions and projections are equivalents to the everyday weather forecast and critical in preparing our society for the weather and climate of the coming years, decades, and centuries. These require an entire value chain of tools from global to regional climate models over observational data and analytical skills to ensure models match reality.

Ocean predictability – variability and long term change

The ocean covers 71% of our globe and plays a central role in the climate system on both short and long time scales. Monitoring ocean conditions from in-situ measurements and remote sensing of the ocean surface provide essential climate variables and aids detection of ongoing climate change as well as understanding of climate variability. The North Atlantic is key for the poleward heat transport and a region where the southern heat meets northern cold – important processes that are strongly sensitive to climate change and affect both Arctic and mid-latitude weather and climate. Knowledge from ocean-sea ice modelling and observations, and the combination of models and observations in increasingly higher resolution is crucial for disentangling the complex processes in the global ocean, the coastal regions, and for interactions with the atmosphere. Understanding these processes, in particular in the North Atlantic, are also central in developing decadal predictions of European weather.

Risks and impacts of climate tipping points

Rapid and/or irreversible changes are of major concern in relation to climate change. Monitoring can aid detection of early warning signals, while an improved process understanding is required to answer if and when certain elements of the climate system are in risk of reaching tipping points. Examples of such elements are the Greenland and Antarctic Ice Sheets and the Atlantic Meridional

Overturning Circulation. Tipping points generally depend on the interplay between several components of the climate system. Tipping points may interact or initiate a cascade of tipping events with potential far-reaching consequences. Detailed modelling and observational studies are needed to assess both the risk and the potential effects of tipping points. The knowledge is key for risk assessments and exploring what lies beyond the most likely. This holds true at the global scale but equally so at a regional and national scale.

National Center for Climate Research at work in Qaanaaq, Greenland

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Scientific approaches

The research and development in NCKF builds on several central disciplines with a main focus on regional and global climate modelling as well as on satellite observations. Through monitoring, modelling, and analysis, we conduct impactful research and development to deliver authoritative scientific knowledge and data related to both long-term climate scenarios for planning purposes and decision making in addition to providing data for operational needs and practical purposes.

Climate modelling
Global climate modelling (also called Earth System Modelling) is key for advancing the knowledge about past and future climate and the overall dynamics of the atmosphere, oceans, and ice sheets. The model EC-Earth, which is developed in an international consortium, is one of the main tools at NCKF, and among other things provide part of the foundation for the IPCC assessments through contributions to the Coupled Model Intercomparison Project, CMIP.

Regional climate modelling builds on global climate modelling and provides a higher level of detail – both geographically and in describing the processes in the climate system. Detailed projections of future climate changes from regional modelling provide the basis for climate services and impact modelling, and are being carried out over Denmark, Europe, Africa, and the Polar Regions. Regional modelling activities thus contribute both to *Klimaatlas* and to the *Coordinated Regional Climate Downscaling Experiment, CORDEX*. In the Polar Regions, our modelling efforts also includes ice flow and surface mass balance modelling of the ice sheets in Greenland and Antarctica. NCKF employs the *HCLIM* regional climate model, which is developed in an international consortium of national weather services, and builds on the numerical weather prediction model *HARMONIE* (also employed at DMI). Our regional modelling also includes operational ocean and sea ice models (*HYCOM-CICE and NEMO*).

Monitoring
Satellite observations and remote sensing are employed for both daily monitoring and observing climate change in the atmosphere, ocean and sea ice, and delivers

daily products and information supporting the societies in Denmark and Greenland and elsewhere. The satellite-based products are also key for evaluating climate models, assessing climate change through spatially detailed time series of essential climate variables and improving the operational model forecasts.

In-situ observations provide 'ground truth' for both satellite observations and climate models. The DMI research station in Qaanaaq in northwestern Greenland provides an ideal site for studying and understanding the mechanisms and interactions between ice, ocean, and atmosphere as the Arctic warms.

Statistics and analyses

While data from models and observations is in itself valuable, it is analysis and assessment that advances the knowledge of the climate system. Statistical methods, including artificial intelligence and machine learning, is a core expertise in NCKF, and is employed at understanding climate trends and changing weather extremes. Future changes are analyzed with both short and long time perspectives (predictions and projections), and the relative impact of natural variability and anthropogenic climate change is assessed through detection and attribution studies.

Danish Meteorological Institute