

Nordic Climate Change Research

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For NordForsk by Mandag Morgen

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1. Executive Summary

This publication describes the focus and strengths of Nordic climate change research, and encompasses both collaborative Nordic research efforts and activities carried out in each of the Nordic countries. Paleoclimatology, climate modelling, atmospheric research and oceanography stand out as particularly strong areas in the Nordic countries. Climate change research is also conducted in areas involving regions, sectors and ecosystems of strategic importance to the Nordic countries, such as the Arctic region, the Baltic Sea, agriculture, forests, wetlands and marine ecosystems.

Despite the relatively small size of the Nordic countries, Nordic researchers play an important role in research on climate change. A recent bibliometric study¹ shows that Sweden, Norway, Denmark and Finland are among the top 20 countries in terms of production of publications related to climate change research. Compared at per capita level, these countries score even higher.

Several Nordic research groups have gained international recognition and as a result climate change research is seen as an area where cross-border collaboration could enhance the international competitiveness of the region as a whole. In 2007, the prime ministers of the Nordic countries agreed that research on climate change should be one of the focus areas for Nordic collaboration. This led to the establishment of the Top-level Research Initiative for climate, energy and the environment in 2008. This initiative is the largest joint Nordic research and innovation programme to date, with a budget of □ 54 million over five years. The initi-

ative is a Nordic contribution towards solving global climate challenges, and seeks to promote research and innovation within the region.

Strengths and Focus of Nordic Climate Change Research

In this publication, Nordic climate change research is described on the basis of categories used by the Intergovernmental Panel of Climate Change (IPCC):

- Climate change – How is the climate changing?
- Climate change drivers – Why is the climate changing?
- Impacts and vulnerabilities – What are the consequences of climate change?
- Adaptation and mitigation – What are appropriate responses to climate change?

The description in this publication of the focus and strengths of Nordic climate change research covers the fields of natural and social science, but does not include technological research on climate mitigation related to energy, industrial production and waste. A selection of research activities is presented for the purpose of illustrating important research themes in the Nordic countries. However, it is recognised that important and relevant research activities outside the scope of this report are also being conducted.

Progress in understanding how the climate is changing has been achieved as a result of improvements in datasets and data analysis, broader geo-

graphical coverage and better understanding of uncertainties. The Nordic countries have developed particular competencies within areas such as climate modelling, understanding climate change in the Arctic region and in paleoclimatological research.

There is a long tradition of climate and environmental monitoring in the Nordic region, and the meteorological institutions in the various countries play a key role in observing climate change and operating databases. Extended time series from Greenland, Iceland and Norway, including Svalbard and Jan Mayen, are important for understanding climate variability in the Arctic and sub-Arctic areas. Due to the Nordic countries' geographical position, observations of oceanic climate change are also significant in Nordic climate change research. The meteorological and marine institutes in the region are mainly responsible for the collection and management of oceanic data, such as data relating to sea level, ocean currents, sea-ice, surface temperature, CO₂ concentration and salinity. The observation of biological and ecosystem parameters related to climate change impact studies is an important area of research at many Nordic universities and environmental institutes.

The Nordic countries host several research stations in the Arctic that carry out Arctic climate change observations. Long-term monitoring programmes of basic meteorological data, solar radiation, surface albedo, atmospheric constituents and spectral reflectance are some of the activities undertaken, as well as monitoring the polar climate, glaciers and ice. Research stations are situated, for example, on Svalbard, in North-East Greenland, in the northernmost parts of Finland and in Sweden.

The Nordic region features an abundance of natural archives of past climate change, such as lakes that are rich in layered sediments, very old tree trunks near the northern tree line and ice in the Arctic. As a result, there is a strong focus on paleoclimatic research in the Nordic countries, involving tapping of terrestrial, marine and ice core archives to study past climate variations. Seabed drilling studies have provided evidence of rapid changes in past ocean thermohaline circulation and surface ocean temperatures on a regional and global scale. Nordic research related to ice-core drilling on Greenland is world famous, especially

the cutting-edge research carried out at the Centre for Ice and Climate at the University of Copenhagen. Information obtained from the drilling of the ice cores is used to develop models to explain observations and predict the ice sheet response to climate change.

The field of climate modelling has evolved over the last decades towards finer spatial resolution, the inclusion of a greater number of physical processes and through comparison to a rapidly expanding array of observations. There are several leading research groups focusing on climate modelling in the Nordic region. The Norwegian Bjerknes Centre for Climate Research was one of four institutions that provided full scenario simulations for the fourth assessment report of the Intergovernmental Panel on Climate Change in 2007. The work on the chapter on regional climate models was led by a researcher from the Danish Meteorological Institute. Regional climate models developed by the Nordic meteorological institutes are among the most advanced in the world, facilitating the production of future climate scenarios, which have provided important input to national adaptation and mitigation strategies.

The drivers of climate change can be divided into two categories: anthropogenic processes and natural climate change. Atmospheric chemistry is an important research area in the Nordic region and aerosol research at the University of Helsinki is at the forefront. Aerosol research aims to reduce the uncertainties related to the impact of aerosol particles on climate change, particularly the interactions between aerosol particles, clouds and climate change. Nordic research centres also contribute significantly to research related to the carbon cycle, such as research on sinks and sources of greenhouse gases in agriculture, forests, peatlands and oceans. Nordic researchers are involved in European projects on the carbon cycle, with a focus on making accurate scientific assessments of the marine carbon sources and sinks, as well as on understanding and quantifying the terrestrial carbon balance of Europe.

The consequences of climate change, impacts and vulnerabilities will vary between geographical regions depending on environmental and social conditions. In the Nordic countries, the rise in

temperature levels is expected to lead to a shift of climate zones in altitude and latitude. Ecosystem modelling and studies of ecological responses to climate changes in the past, aimed at achieving a better understanding of the future impacts of environmental changes, are thus important research areas. Ocean currents, the distribution and size of fish populations and acidification of the oceans are key research themes relating to impacts on the marine ecosystem.

Nordic research on climate impacts and vulnerability focuses increasingly on the consequences of climate change for society and the economy. Impact assessments for important economic sectors such as agriculture, energy production and forestry have been given priority, as has research on how projected changes in climate interact with changes in socioeconomic and institutional conditions. Several ongoing projects focus on research supporting local climate change assessments.

Climate change adaptation and mitigation have gained increased attention as knowledge about climate changes has improved. In the Nordic region, several former and current collaborative research projects address climate change adaptation in an effort to promote the development and implementation of adaptation measures at the national and local level and in specific sectors. Finland, in particular, has been at the forefront in developing adaptation strategies. In 2005 it published one of the world's first national adaptation strategies.

Nordic research on climate adaptation focuses, amongst other things, on social processes that influence the capacity to adapt. Another issue is the limits of adaptation to climate change and the implications of these limits for human security. As regards climate change mitigation, many research projects involving Nordic researchers focus on the use of policy tools and international climate agreements. Other important research areas include land use and the way in which measures related to forests and cultivated land can play a part in mitigating climate change.

The Global Perspective and Climate Change Research in the Years to Come. The task of advancing the understanding of the processes that determine the Earth's climate is a global one, and inter-

national cooperation within climate change research is widespread. Nordic climate change researchers are involved in a large number of international projects, with European research cooperation as the most important arena. At the global level, there are a number of international organisations, agencies and non-governmental organisations (NGOs) that facilitate climate change research cooperation. The Nordic countries participate in many of these initiatives, including the four global change research programmes in the Earth System Science Partnership (ESSP), as well as international networks for climate observations and monitoring.

On a global scale, it is clear that the developing countries are the most vulnerable to climate change. A long line of reports have concluded that expected climate changes could threaten the achievement of the Millennium Development Goals aimed at fighting poverty. In this context, research plays an important role in providing vital input for decision-makers. Nordic researchers are actively engaged in a wide range of climate-related research areas relevant to developing countries, such as regional climate modelling, water and resource management, agricultural research, international climate agreements and funding mechanisms for climate mitigation and adaptation in the developing world.

Over the last decade, there has been significant progress in understanding and projecting climate change, and scientific information is still being accumulated at a rapid pace. Nevertheless, much uncertainty remains and research is needed in order to fill the knowledge gap. In light of the urgent need to develop strategies for meeting the climate change challenge, cooperation between scientists and policy-makers has increased considerably in the last few years. Moreover, in order to meet the needs of decision-makers and to enhance the decision-making process, climate change research is taking an increasingly cross-disciplinary approach and is often related to specific societal challenges. In the years to come, these general trends in climate change research are likely to be reinforced. Research that can reduce uncertainty, in addition to adaptation and mitigation research such as research on the economy of climate change and the topic of climate change and human security, are likely to emerge as priority research areas.



2. Sammendrag

Publikasjonen «Nordic Climate Change Research» presenterer prioriteringer og styrkeområder innenfor nordisk klimaforskning, med fokus både på forskningssamarbeid i regionen og på aktiviteter i de enkelte landene. De nordiske landene har spesielt sterk kompetanse innenfor blant annet paleoklimatologi, klimamodeller, hav- og atmosfæreforskning. Dessuten bidrar nordiske forskere med klimaforskning relatert til regioner som er strategisk viktige for de nordiske landene, som Arktis og Østersjøen, samt sektorer og økosystemer som landbruk, skog, våtmarker og marine økosystemer.

En nylig bibliometrisk studie² viser at Sverige, Norge, Danmark og Finland er blant de 20 beste landene når det gjelder produksjon av klimaforskningspublikasjoner. Dersom man sammenligner tallene på et *per capita* nivå gjør landene det enda bedre.

Med flere internasjonalt anerkjente forskergrupperinger i Norden ser man for seg at klimaforskning er et område hvor økt samarbeid vil føre til styrket internasjonal konkurranse-dyktighet for regionen. I 2007 ble de nordiske statsministrene enige om at klimaforskning skal være et av fokusområdene for nordisk samarbeid, noe som ledet til lanseringen av Toppforskningsinitiativet i 2008. Dette er det største nordiske samarbeidsprosjektet innenfor forskning og innovasjon gjennom tidene og har et budsjett på 54 millioner euro som strekker seg over fem år. Initiativet er et nordisk bidrag til å løse den globale klimakrisen, samt fremme

forskning og innovasjonen i den nordiske regionen.

Styrker og fokusområder i nordisk klimaforskning

Denne publikasjonen har benyttet rammeverket i FNs klimapanel til å kategorisere nordisk klimaforskning:

- Klimaendringer – hvordan endrer klimaet seg?
- Drivkrefter bak klimaendringene – hvorfor endrer klimaet seg?
- Effekter og sårbarheter – hva blir konsekvensene av klimaendringene?
- Tilpasning og utslippsreduksjoner – hvordan bør klimaendringene håndteres?

Oversikten i denne rapporten over nordiske fokusområder og styrker innen klimaforskning dekker natur- og samfunnsvitenskap, men ikke teknologisk forskning på tiltak relatert til energi, industriproduksjon og avfall. Et utvalg av forskningsaktiviteter presenteres for å illustrere viktige forskningsområder i de nordiske landene, men viktig og relevant klimaforskning foregår også utover det som er nevnt i denne publikasjonen.

Forståelsen for hvordan klimaet endrer seg har blitt bedre takket være bedre data og data-analyser, bredere geografisk dekning, og bedre forståelse av usikkerheter. De nordiske landene har utviklet særlig kompetanse på områder som klimamodellering, forståelse av klimaendringer i Arktis og paleoklimatologisk forskning.

Klima- og miljøovervåkning har lange tradisjoner i Norden og landenes meteorologiske institutter er hovedaktører når det gjelder observasjoner av klimaendringer og operasjon av databaser. Lange tidsserier fra Grønland, Island og Norge, inklusive Svalbard og Jan Mayen er viktige for forståelsen av klimavariasjoner i Arktis og Subarktis. Grunnet de nordiske landenes geografiske plassering er også havklimaobservasjoner et viktig område i nordisk klimaforskning. De meteorologiske og marine instituttene står i hovedsak bak innsamlingen og administrasjonen av havdata som bl.a. havnivå, havstrømmer, havis, overflate-temperaturer, CO₂-konsentrasjon og saltnivå, mens nordiske universiteter og miljøinstitutter gjerne står for observasjoner av biologiske og økologiske parametere.

Det finnes flere forskningsstasjoner for arktiske klimaobservasjoner i de nordiske landene. Langtidsovervåkning av meteorologiske data, solstråleenergi, overflate-albedo, atmosfæriske bestanddeler og spektral refleksjon er noen av aktivitetene på disse stasjonene, sammen med overvåkning av polarområdene, isbreer og is. Forskningsstasjoner finner man for eksempel på Svalbard, nordøst-Grønland, i de nordligste delene av Finland og i Sverige.

I Norden finnes tallrike naturlige lagre av informasjon om tidligere klimaendringer, både i innsjøer som er rike på lagvise sedimenter, i gamle trestammer nær den nordlige tre grensen og i is i Arktis. Dette gir grunnlag for et sterkt fokus på paleoklimatologisk forskning i de nordiske landene med tapping av marine arkiver, jord- og iskjernearkiver for å studere historiske klimavariasjoner. Boring i havgrunnen har gitt bevis på raske endringer i termohalin sirkulasjon og overflatetemperaturer i havet på regionalt og globalt nivå. Boring av iskjerner på Grønland er et forskningsområde hvor den nordiske regionen har spesielt sterk kompetanse, med Senter for Is og Klima ved Universitetet i København i verdens toppen innenfor dette forskningsområdet. Dataene som utvinnes gjennom iskjerneboring brukes til å utvikle modeller for å forklare observasjoner og forutse isens respons på klimaendringer.

Klimamodellering har utviklet seg de siste tiårene gjennom høyere oppløsning, inkludering av et større antall fysiske prosesser og sammenligning med et raskt voksende datasett av observasjoner. Flere nordiske forskergrupper er gode på klimamodellering. Bjerknes-senteret i Norge var en av fire institusjoner som bidro med fullscenariosimulering til FNs klimapanelers fjerde rapport i 2007. Arbeidet med kapittelet om regional klimamodellering i rapporten ble ledet av en forsker fra Danmarks Meteorologiske Institutt. De regionale klimamodellene som har blitt utviklet av de nordiske meteorologiske instituttene er noen av de mest avanserte regionale klimamodellene i verden. De muliggjør produksjonen av fremtidige klimascenarier, noe som er spesielt viktig for utformingen av nasjonale planer for tilpasning og utslippsreduksjoner.

Drivkreftene bak klimaendringer kan deles inn i to grupperinger; menneskeskapte prosesser og naturlig klimaforandring. Atmosfærekjemi er et viktig forskningsområde i Norden, og forskningen på aerosoler ved Universitetet i Helsingfors er ledende på området. Denne forskningen søker å redusere usikkerhetene relatert til den påvirkningen som aerosolpartikler har på klimaendringer, og da særlig når det gjelder interaksjonen mellom aerosolpartikler, skyer og klimaendringer.

Nordiske forskningssentra kan også bidra betydelig til forskning relatert til karbon-syklusen som blant annet karbonsinks og kilder til drivhusgasser i landbruk, skog, torvland og hav. Nordiske forskningssentra er også involvert i europeiske prosjekter som fokuserer på karbonsyklusen ved å kvantifisere utslipp og lagring av klimagasser fra hav og land i Europa.

Konsekvensene av klimaendringer og sårbarheter vil variere mellom geografiske regioner avhengig av miljømessige og sosiale forhold. Temperaturøkningene er forventet å føre til endringer av klimasoner i Norden. Modellering av økosystemers historiske respons på klimaendringer for bedre å forstå virkningene av miljøforandringene i fremtiden er derfor viktige forskningsområder i nordiske land.

Når det gjelder innvirkninger på det marine økosystemet, er særlig havstrømmer, fiskebestandens utbredelse og størrelse, samt forsurenningen av havet sentrale forskningstemaer.

Nordisk forskning på effekter og sårbarheter av klimaforandringene fokuserer mer og mer på konsekvensene på samfunn og økonomi. Vurderinger av klimaendringenes betydning for viktige økonomiske sektorer som jordbruk, energiproduksjon og skogbruk har blitt prioritert sammen med forskning på forventede klimaendringers vekselvirkning med endringer i sosioøkonomiske og institusjonelle forhold. Flere pågående forskningsprosjekter fokuserer på analyse av effekter av klimaendringer på lokalt plan.

Forskning relatert til utslippsreduksjoner og tilpasning til klimaendringene har fått økt oppmerksomhet i takt med at kunnskapen om klimautfordringen har økt. I Norden har flere tidligere og pågående flerpartsprosjekter hatt fokus på tilpasning til klimaendringer med mål om å bidra til utviklingen og implementeringen av tilpasningstiltak på nasjonalt og lokalt nivå, samt innenfor spesifikke sektorer. Særlig har Finland vært et foregangsland når det gjelder klimatilpasning, og landet lanserte en av verdens første tilpasningsstrategier i 2005.

Nordisk forskning på tilpasning fokuserer blant annet på sosiale prosesser som påvirker evnen til tilpasning. Andre områder det forskes på er begrensningene til tilpasning som et svar på klimaendringer, og implikasjonene som dette kan ha for menneskers sikkerhet. Når det gjelder tiltak for å redusere klimagassutslipp, fokuserer mye nordisk forskning på bruken og effekten av politiske verktøy og internasjonale klimaavtaler. Andre viktige forskningsområder inkluderer landbruk og hvordan tiltak relatert til skog og dyrket mark kan bidra til å redusere klimaendringene.

Globalt perspektiv og klimaforskning i årene som kommer

Prosessene som avgjør klimautviklingen er globale av natur, og internasjonalt samarbeid er utbredt når det gjelder klimaforskning. Nordiske klimaforskere er involvert i et stort

antall internasjonale prosjekter, særlig i europeisk regi. På globalt nivå finnes en rekke internasjonale organisasjoner, byråer og ikke-statlige organisasjoner som bidrar til samarbeid innenfor internasjonal klimaforskning. De nordiske landene deltar i mange av disse initiativene, inkludert de fire globale klimaforskningsprogrammene innenfor Earth Systems Science Partnership (ESSP), så vel som internasjonale nettverk for klimaobservasjoner og -overvåkning.

På globalt nivå er det ingen tvil om at utviklingsland er mest sårbare overfor klimaforandringene. En rekke rapporter har konkludert med at et endret klima kan stå i veien for gjennomføringen av FNs tusenårsmål om å bekjempe fattigdom. I denne sammenhengen spiller forskning en viktig rolle som informasjonsgrunnlag for beslutningstakere. Nordiske forskere bidrar på en lang rekke klimarelaterte forskningsområder som er relevante for utviklingsland, som blant annet regional klimamodellering, vann- og ressursforvaltning, jordbruksforskning, internasjonale klimaavtaler og finansieringsmekanismer for tiltak og tilpasning i utviklingsland.

I løpet av det siste tiåret er det gjort betydelig fremgang når det gjelder å forstå klimaendringene. Den vitenskapelige kunnskapen vokser raskt, men det gjenstår likevel viktig forskning for å fylle noen av kunnskapslukene slik at usikkerheter kan reduseres ytterligere. Grunnet et sterkt behov for å utvikle planer for å takle klimautfordringen har samarbeidet mellom forskere og de som utformer den offentlige politikken økt betraktelig de siste årene. Videre har klimaforskning i langt større grad blitt gjennomført interdisiplinært, organisert rundt spesifikke sosiale utfordringer. Dette gjøres for å møte beslutningstakeres krav, og for å kunne bidra i beslutningsprosessen. I årene fremover er det sannsynlig at disse generelle trendene i klimaforskning vil fortsette. Prioriterte forskningsområder vil antagelig være de som kan redusere usikkerhetsfaktorer, men også forskning innenfor tilpasning og motvirkning, som for eksempel forskning innenfor klimaøkonomi, og klimaforandringene og menneskers sikkerhet.



3. Introduction

The Nordic Countries - Denmark (including the Faroe Islands and Greenland), Finland (including Åland), Iceland, Norway and Sweden - have a long tradition of regional cooperation, including co-operation on research and development. The main framework for Nordic research and development cooperation is the Nordic Research and Innovation Area (NORIA), where the aim is to make the Nordic region a leading region in research and innovation. NordForsk, the Nordic research board under the Nordic Council of Ministers, is one of the pillars of NORIA.

NordForsk focuses on research areas in which the Nordic countries are internationally recognised and promotes research and researcher training of high international quality. NordForsk develops and utilises research funding instruments that seek to create synergies that supplement existing national investments in research.

Climate change research is one of the areas that have been found especially relevant for Nordic collaboration. Many Nordic research groups are internationally renowned, and climate change research is a prioritised area in the Nordic countries. It is recognised as an area where Nordic collaboration increases international competitiveness. Former and present Nordic research funding initiatives have focused on this area.

In 2007, the prime ministers of the Nordic countries agreed that research on climate change should be one of the focus areas for Nordic collaboration. This led to the establishment of the Top-level Research Initiative for climate, energy

and the environment in 2008. This initiative is the largest joint Nordic research and innovation programme to date, with a budget of □ 54 million over five years. The initiative is a Nordic contribution towards solving global climate challenges, and seeks to promote research and innovation within the region.

This policy brief presents areas of Nordic strength within climate change research. This includes both areas where the Nordic countries collaborate as a result of common priorities and areas where the individual countries are strong, but where there is no formal Nordic cooperation. A potential for new Nordic cooperation may be found in the latter category.

This publication is part of a series of policy briefs published by NordForsk. The series aims to stimulate the political debate on research policy issues and is usually intended for Nordic policy makers and research funding organisations. This policy brief, however, is not only meant for a Nordic audience, but also for an international reader who wants to learn more about the Nordic efforts within climate change research. The publication will be presented at the United Nations Climate Change Conference in Copenhagen 2009.

3.1 CONTENT, SCOPE AND METHODOLOGY

As a starting point for the description of strengths and focus areas within Nordic climate change research, we present a general picture of Nordic

NordForsk

NordForsk is the Nordic research board operating under the Nordic Council of Ministers for Education and Research, responsible for Nordic collaboration in research and research training. NordForsk coordinates important research priorities that have been identified as suitable for joint Nordic efforts, concentrating its efforts on research areas where the Nordic countries have an international position of strength. NordForsk has three roles: coordination, financing and policy advice. www.nordforsk.org

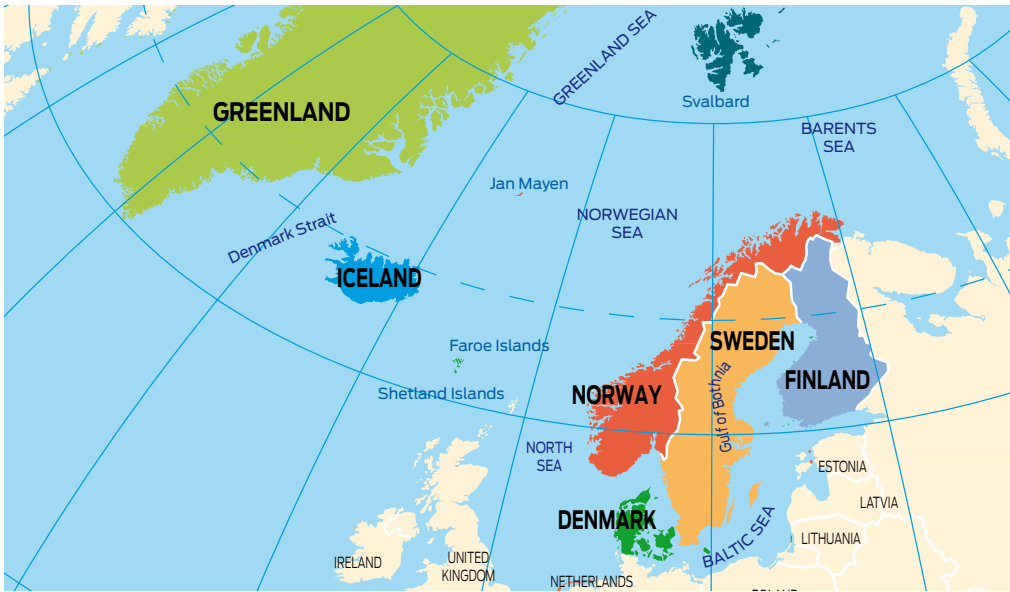


FIGURE 1: Map of countries in the Nordic region³

Facts about the Nordic Region

The Nordic region has a population of 25 million. The Nordic countries consist of Denmark, Finland, Iceland, Norway and Sweden, as well as the autonomous territories Faroe Islands, Greenland and Åland.

Key figures (2007)

	Population	BNP/capita	GHG-emissions/capita
Denmark	5.4 million	€ 30,900	12.2 tonnes CO ₂ equivalents
Finland	5.3 million	€ 29,400	14.8 tonnes CO ₂ equivalents
Iceland	310,000	€ 32,100	14.2 tonnes CO ₂ equivalents
Norway	4.7 million	€ 46,100	11.9 tonnes CO ₂ equivalents
Sweden	9.1 million	€ 30,700	7.1 tonnes CO ₂ equivalents

Source: Nordic Statistics, <http://ww3.dst.dk/pxwebnordic/Dialog/statfile1.asp>

priorities on a regional and national level in chapter 4. It includes joint Nordic initiatives, national priorities and major research programmes in the individual countries, as well as a presentation of some of the most important climate change research institutes and centres. A more detailed overview of research in various areas can be found in Chapter 5, where we apply the framework of the Intergovernmental Panel of Climate Change (IPCC)⁴ to describe Nordic climate change research in four different areas:

- Climate change
- Climate change drivers
- Impact and vulnerabilities
- Adaptation and mitigation

These areas represent sub-sections in Chapter 5. In each sub-section, a selection of activities and research projects is presented, with the purpose of illustrating Nordic research focus and strengths within climate change research.

Many of the research projects mentioned in Chapter 5 are international research projects. Nordic climate change researchers take an active role in international research cooperation at a Nordic, European and global level. This is further explored in Chapter 6, where we describe some of the international climate change related initiatives in which Nordic climate change researchers participate. The global nature of the climate change challenge also motivates a special focus on climate change research relevant for developing countries, which is the topic for Chapter 7. Finally, this publication concludes with a chapter describing some

of the current trends that might influence climate change research in the years to come.

The scope of this publication is limited by our definition of climate change research. It is based on the framework of the IPCC, which includes the four areas mentioned above. However, an important exception is made as this publication does not cover research related to mitigation by technological solutions connected with energy supply, energy use, transport, industrial production or waste. These areas are excluded mainly because they are covered in a series of reports related to renewable energy and clean technologies that are being published by Nordic Energy Research⁵. The scope of this publication is also confined by the fact that only research at universities, research institutes and centres is included, while research and development in the private sector is excluded.

Methodology

In preparing this publication, information has been collected based on a qualitative approach, and our conclusions of the strengths and priorities in Nordic climate change research are based on direct input from researchers and of studies of existing documentation from political authorities, funding agencies, universities and other centres for climate change research. Our main sources of information have been:

1. A survey among climate change researchers

Researchers from a dozen institutions and centres for climate change research have answered a questionnaire by e-mail or telephone interviews. The survey included questions about research at the respondent's institution, as well as the respondent's view on Nordic climate change research in general – its successes, strengths and future research needs.

2. Existing studies and documentation

The written sources include documentation (including web sites, evaluations, strategy documents, project descriptions, etc.) from universities and climate change research centres, information about individual research projects and programmes, as well as different reports and policy documents. Examples of important written sources

are National Communication on Climate Change to the IPCC⁶ from each of the Nordic countries, which all include a chapter on climate change research. Other overviews, such as the "Report on the current state of National Research Programmes on Climate Change Impacts and Adaptation in Europe" published by the CIRCLE ERA-Net scheme in 2008, have also been useful. For information about EU-funded research projects and programmes, the European Commission CORDIS web page has been an important source of information.

3. A workshop

An early draft of this publication was discussed at a workshop that gave valuable input to the final editing of the document. The workshop had 15 participants from political authorities, funding agencies and research institutions, as well as from Nord-Forsk and Mandag Morgen.

Based on studies of the information from the sources listed above, a limited number of research themes were identified as focus areas and/or areas of excellence. These areas are illustrated by examples of research activities in Chapter 5.

For more details about the survey, the workshop and the reference group, see Appendix B.

Nordic Council and Nordic Council of Ministers

The Nordic Council of Ministers, established in 1971, is the forum for collaboration between the Nordic governments. The Nordic Council of Ministers works towards joint Nordic solutions on issues of great importance to the member states. Some of the outcomes of this work are a joint Nordic labour market, a passport union and a range of joint social provisions.

The Nordic Council was founded in 1952 following World War II, when a need for increased collaboration between the Nordic countries emerged. The Nordic Council is the official inter-parliamentary body in the Nordic Region. The Council has 87 elected members from Denmark, Finland, Iceland, Norway and Sweden as well as from the three autonomous territories; the Faroe Islands, Greenland and Åland. Political discussions are held with members of the governments of the five Nordic countries and the three autonomous territories at the annual Session of the Nordic Council. It is a unique form of international co-operation.

www.norden.org



4. Climate Change Research Priorities in the Nordic Region

A recent bibliometric study⁷ reveals that the activities within climate change research in the Nordic region are extensive. The study shows that climate change researchers affiliated with Nordic institutions have a high productivity of publications from an international point of view. Sweden, Norway, Denmark and Finland are all among the top 20 countries with the most publications within this research field.

If one relates the number of publications to the number of inhabitants of the countries, the Nordic countries score even higher. According to the Danish study, Norway has the highest number of scientific publications within climate change in the world per inhabitant. Sweden, Denmark and Finland rank from number 4 to 6 on this list (see Figure 2 and 3).

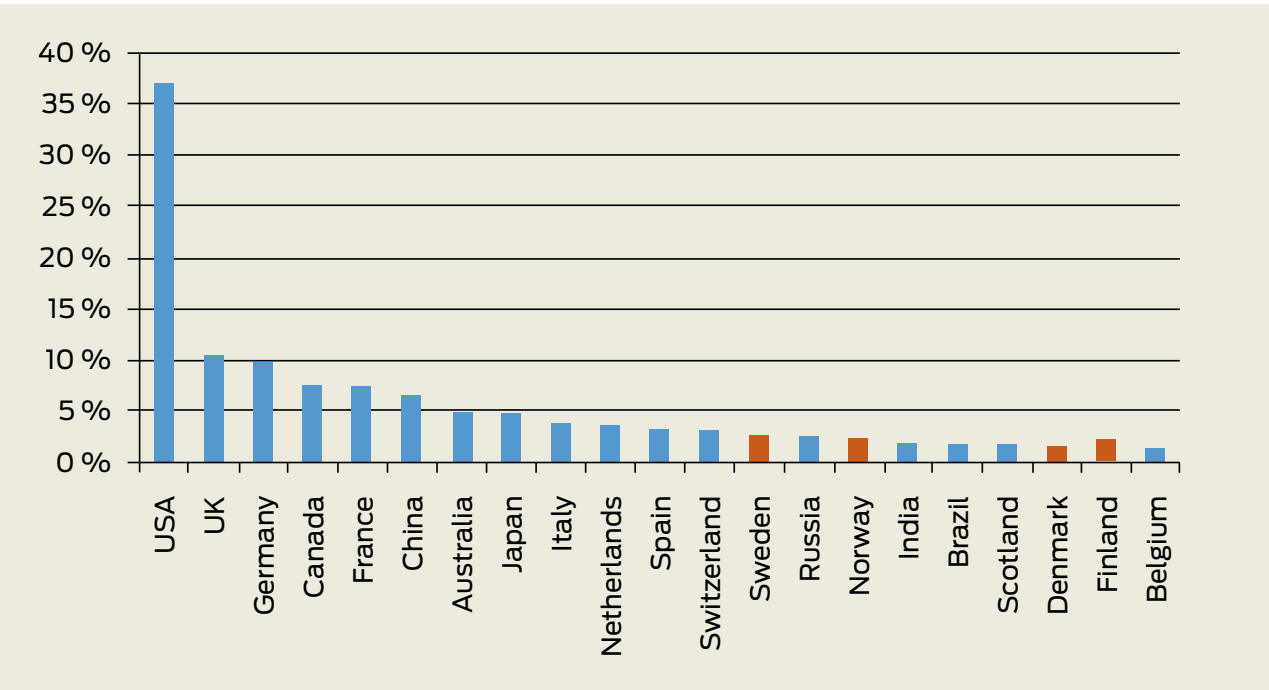


FIGURE 2: Share of publications among the top 20 countries with most scientific publications within climate change⁸

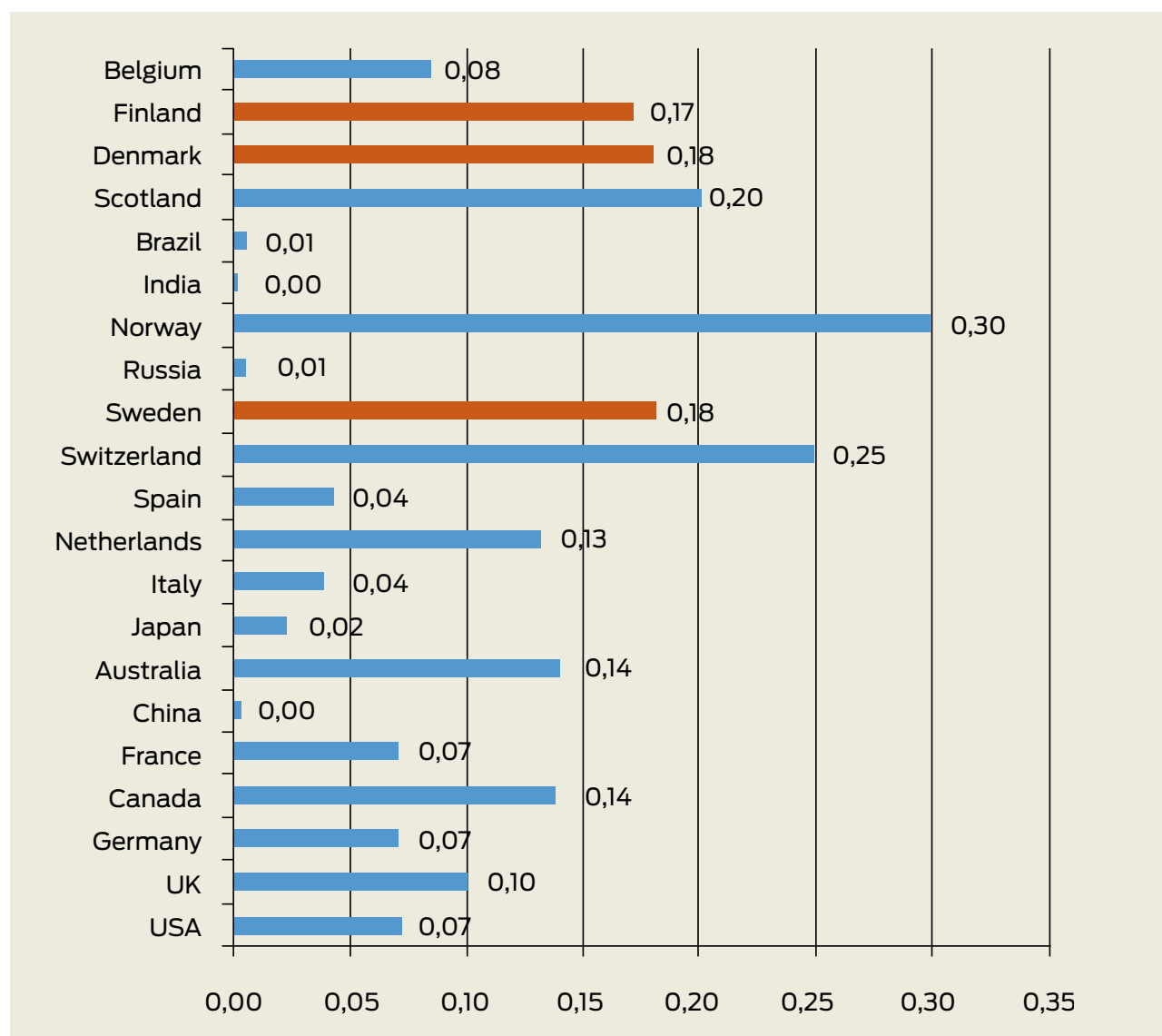


FIGURE 3: Number of scientific publications within climate change per 1000 inhabitants⁹

About the Bibliometric Survey

The bibliometric survey of climate research in Denmark is based on 58,592 scientific publications on climate identified in the interdisciplinary database "Web of Science" for 2003-2007. The survey was carried out by the Royal School of Library and Information Science at the request of the Danish Agency for Science, Technology and Innovation, and it was implemented between November 2008 and January 2009. The bibliometric survey covers only peer-reviewed articles and, to a limited extent, contributions to conferences. Books and reports written as part of authorities processing are not included. The publications were identified by means of a search strategy grounded on words and phrases related to the area of climate. The search strategy was based on the Danish Agency for Science, Technology and Innovation's definition of climate research, The Hot Topic by Walker & King (2008), and various reports from IPCC.

4.1 NATIONAL CLIMATE CHANGE PRIORITIES

The Nordic countries have increased their emphasis on climate change research as a strategically important research area. In this section, we describe political priorities, major research programmes and funding organisations. Climate change research covers a wide array of scientific fields, which complicates the collection of information about funding of climate change research. In most cases, research funds are not narrowly directed at climate change, but are allocated to individual researchers and research groups working with climate related research within different disciplines. There is no aggregated comparable data on Nordic funding of climate change research, but the sections below include some figures that are available and give a rough indication of the levels of funding. In addition to national funding, the EU Framework Programme for Research and Technological Development is an important source of financing for climate change research in the Nordic countries.

Denmark

Important input to Danish research policy was published in the RESEARCH2015-catalogue in 2008¹⁰. The catalogue was the result of a process during which a substantial part of the Danish society contributed to the identification of the 21 most promising future research areas for Denmark. Energy, Climate and Environment is one of these strategic areas. The document identifies several research needs in the sub-area Future Climate and Climate Adaptation, arguing that a strategic research effort should “reduce the uncertainties regarding climate change and its effects and support future climate policy decisions with respect to counteracting – and adapting to – a changeable climate”. Interdisciplinary research and strong coordination are mentioned as important success factors in this area. In a report published in May 2009¹¹, the Danish Coordination Unit for Research in Climate Change Adaptation at Aarhus University suggests five core themes for future focus on adaptation research:

- Models and climate change adaptation
- Society and climate change adaptation

- Construction and climate change adaptation
- Landscape and climate change adaptation
- Climate change adaptation in coastal areas

It is expected that Danish funding to climate change research will be strengthened in the years to come. The report from the Coordination Unit for Research in Climate Change Adaptation provides input to the negotiations over distributions of the resources set aside for research and development in the Danish Government’s strategy to deal with globalisation. In 2009, the allocation to research in climate and climate change adaptation is □ 5.8 million¹² and □ 2.7 million to the establishment of a new climate research centre in Greenland. In October 2009, the Danish Council for Strategic Research granted □ 4 million for a new interdisciplinary centre for regional climate change research. For the most part, climate change research in Denmark is funded by the institution’s basic grants and programme grants, but a number of research councils and programmes also offer financial support to climate change related research.

Finland

Adaptation to climate change has been a priority in Finland, and the country was a front-runner when it adopted a National Strategy for Adaptation to Climate Change in 2005¹³. The FINADAPT consortium studied adaptation to the potential impacts of climate change in Finland during 2004-2005, as a part of the Finnish Environmental Cluster Research Programme, co-ordinated by the Ministry of the Environment.

Today, Finland’s Climate Change Adaptation Research Programme (ISTO) aims to support the implementation of the national adaptation strategy. This programme is also funded by the Environment Cluster Research Programme of the Ministry of the Environment and by the Ministry of Agriculture. It was launched in 2006 and runs until 2010, focusing on giving a more accurate view of the risks of climate change in different sectors. During the first two years (2006-2008), 18 projects were funded under the ISTO programme by approximately □ 0.5 million a year. Climate-change-related research is also conducted within the Research program for Global Change at the Finnish Environment Institute (SYKE).

A foresight report¹⁴ published by the Finnish government in October 2009 indicates the need to increase research in the following areas: Research regarding extreme and abrupt climate changes and feedbacks, research on how the society's structure affects emissions, food production and climate change, climate policy and cost efficiency, and research supporting climate policy and decision making.

Basic research in Finland is mainly funded by the Academy of Finland or the National Technology Agency (TEKES). For the period after 2010, the Academy of Finland is now preparing a new four-year integrated climate change research programme "Climate Change; governance, mitigation and adaptation" (FICCA). It will have a budget of € 10 million over four years. The research programme has a suggested focus on basic, future research challenges, relating to the problems of management and the mitigation of climate change, as well as ways of adapting to it. Four initial topics have been discussed:

- Climate-induced changes in the environment
- Climate change induced effects in the society
- Society's and the environment's adaptation to climate change and its effects
- Public policy and technological solutions for climate change mitigation

Iceland

According to Iceland's fourth National Communication on Climate Change to the United Nations Framework Convention on Climate Change, published in 2006, environmental change is recognised as an important area in research and development. This is confirmed in the climate strategy, published in 2007. Given Iceland's small size, emphasis is put on international cooperation and Icelandic climate change researchers benefit from a high level of participation in international research projects. Recently, two groups of scientists and specialists, led by the Icelandic Meteorological Office (IMO) and the University of Iceland, have worked on a Climate Change Impact Assessment¹⁵ for Iceland and on a long-term Mitigation Strategy¹⁶. The work has included research on adaptation, in respect to changes in physical and biological systems, as well as certain

sectors of the economy. The groups have recently delivered the reports on their findings to the Minister of Environment.

Norway

Over the last period, the Norwegian government has given priority to funding research in carbon capture and storage, but the government has announced that it will strengthen funding for climate change research in the years to come. In 2008, six out of seven parties in the Norwegian parliament agreed to strengthen climate change research in Norway. At the moment, a strategic group called Klimaz1 is preparing a plan for increasing the resources to climate change research, including suggestions for priorities. The work of the group is based on the action plan of the National Commission of Climate Change Research, which published its report in 2006¹⁷. Klimaz1 will focus its work on four basic research areas:

- Climate science
- Mitigation
- Analyses of social constraints and climate policy instruments
- Adaptation to climate change

Today, approximately 50 per cent of climate change research in Norway is channelled through the Research Council of Norway, within the framework of the programme "Climate change and its impacts in Norway" (NORKLIMA), and by in-kind contributions from research institutions. NORKLIMA is a large-scale research programme that was launched in 2004, and it will run until 2014. The objective of the programme is to generate vital new knowledge as a basis for adaptive responses by human society. The main focus is on the climate system; climate trends in the past, present and future; and direct and indirect impacts of climate change on the natural environment and society. Its annual funding has increased in recent years, amounting to over € 13 million in 2008. The total funding of climate change research, excluding mitigation, through the Norwegian Research Council has amounted to approximately € 23 million¹⁸, broken down as follows:

GIVEN ICELAND'S
 SMALL SIZE,
 EMPHASIS IS
 PUT ON
 INTERNATIONAL
 COOPERATION
 AND ICELANDIC
 CLIMATE CHANGE
 RESEARCHERS
 BENEFIT FROM
 A HIGH LEVEL OF
 PARTICIPATION IN
 INTERNATIONAL
 RESEARCH
 PROJECTS.

- Climate science and climate change (□ 14 million)
- Impacts and adaptation (□ 8 million)
- Climate policies (□ 1 million)

Sweden

In the Swedish bill on research and innovation¹⁹ presented by the Government in October 2008, climate change research is one out of three main areas, along with technology and medicine, which are distinguished as “strategic research areas”. Within the area of climate change research, the following themes are highlighted as especially important:

- Sustainable use of natural resources
- Impacts on natural resources
- Climate modelling
- Ocean environment research

These areas will receive additional funding in 2010-2014, and the Swedish research councils have suggested that a total of □ 13 million should be distributed within these areas.

According to preliminary statistics that will be published in Sweden's next National Communication on Climate Change, funding to climate change related research in 2005-2008 was, on average □118 million²⁰ per year. Most of this amount, approximately □ 80 million, was funding to climate-change-related energy research, while the rest has been given to research in the climate system, impacts and adaptation. This is a considerable increase from the funding provided in the 2002-2005 period, when the total funds amounted to □ 42 million per year²¹.

The two main funding organisations supporting basic climate change research are the Swedish Research Council and the Swedish Research Council for Environment, Agricultural Science and Cultural Planning (FORMAS). Furthermore, several foundations and governmental sector agencies also fund climate change related research. The Swedish Foundation for Strategic Environmental Research (Mistra) is one of these, currently funding two major programmes: the “Research Programme on Climate, Impacts and Adaptation” (Mistra-SWECIA) and “Climate Policy Research Programme” (Clipore), described in Chapter 5.

FEATURED SCIENTIST: MARKKU RUMMUKAINEN

Supporting action on climate

Being responsible for major Swedish climate change research programmes and author of numerous reports explaining expected climate change and its associated risks, Markku Rummukainen plays an important role in the support to Swedish climate change policy and stakeholder action.

“I came across climate change topics already while studying in the 1980s, but started with climate research first in 1997. It was part curiosity and part scientific challenges that lead me in that direction, as well as I wanted to do science that could directly provide decision-support to society and stakeholders”, Rummukainen explains.

Today, he is Climate Advisor at the SMHI Core Services Department and Programme Director for the major climate research programme Mistra-SWECIA. The latter combines research on climate modelling, climate economy, climate impacts and adaptation processes. The programme forms new interdisciplinary models and approaches in collaboration with stakeholder networks to gain improved capacity for advanced analysis and assessment

to support the climate change adaptation of the society.

“We need to improve dialogue between scientific knowledge providers and users”, Rummukainen says and continues: “We already have a lot of information about climate change. When the knowledge is put into practical use, we can

see what we need to study further. There remains more to be learnt about the physical climate system and how it interacts with biological systems”. With these beliefs, Rummukainen also has some thoughts on how to move forward: “In the Nordic region, we have a lot of climate science expertise

and can benefit from improved research co-operation and coordination, such as new joint efforts in complementary research efforts”.

With his position within the Nordic research environment in general and the Swedish research environment in particular, it is certain that Rummukainen can use his influence to promote exactly those ideas: moving the policy makers into more action and bringing scientific disciplines even closer together.

WE NEED TO
IMPROVE
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SCIENTIFIC KNOW-
LEDGE PROVIDERS
AND USERS.



4.2 IMPORTANT INSTITUTES AND CENTRES OF CLIMATE CHANGE RESEARCH

The Nordic countries are home to a large number of research institutions and hubs that conduct research related to climate change. In this section, we present a selection of some of the most important ones, with a focus on the meteorological institutes, the largest groups focusing on climate change research, as well as other centres related to these. Some other institutes are also described to illustrate special focus areas. However, although specialised institutes and centres such as marine, atmospheric, agricultural and geological institutes provide important contributions to climate change research, they are not included in this list. For a more comprehensive list of relevant universities, centres and institutes, see Appendix A.

Denmark

The **Danish Meteorological Institute** (DMI) manages the meteorological, climatological and oceanographic services to Denmark, the Faeroe Islands and Greenland. The **Danish Climate Centre** was established at DMI in 1998, and its research includes developing models for describing and predicting changes in the atmosphere, climate and oceans. The competence within climate modelling at the Danish Climate Centre is world class; research leader Jens Hesselbjerg Christensen had the role as coordinating lead author in the chapter on regional climate models in IPCCs fourth assessment report published in 2007, and the centre has managed several international research projects.

For historical records of climate changes, Danish research competence can be found, among others, at the two largest Danish universities: the **University of Copenhagen** and **Aarhus University**. Greenland is vital for research in climate variability at the **Centre for Ice and Climate** at the University of Copenhagen, which is world famous for its activities related to the drilling of ice cores through the Greenland ice sheet. It is a Centre of Excellence funded by the Danish National Research Foundation. The University of Copenhagen also conducts climate change research within several other areas, for example, earth system science, atmospheric

science, global warming and the cryosphere, natural resources management, environment and food security, biodiversity and ecology, environmental governance, etc. Within social sciences, professor in anthropology Kirsten Hastrup has received a prestigious Advanced Investigator Grant from the European Research Council (ECR), which is being used to establish a climate centre at the Institute for Anthropology.

At **Aarhus University**, all of the main academic areas have individual fields of research related to environmental and climate change. One special unit at Aarhus University is the **National Environmental Research Institute** (NERI). NERI monitors the environment and conducts applied and strategic research, contributing to important research on the effects of climate change on ecosystems. Other focus areas are the atmospheric environment and environmental analyses within a social science perspective. The Policy Analysis department at NERI has established a Co-ordination Unit for Climate Change Research²².

Climate change research at the **Danish Technical University** (DTU) focuses especially on technology, but other climate-change-relevant research is also conducted. A new Climate Centre was established at DTU in 2008, located at the **Risø DTU National Laboratory for Sustainable Energy**. Producing scenarios and analyses of the effects of different mitigation strategies is one of the key areas of research at the new centre. The **UNEP Risø Centre on Energy, Climate and Sustainable Development** is associated with Risø DTU and supports the United Nations Environment Programme (UNEP) in its aim to incorporate environmental and development aspects into energy planning and policy worldwide. Research focus is on energy and development, including the emerging carbon markets and the Clean Development Mechanism.

Finland

The **Finnish Meteorological Institute** (FMI) coordinates the Finnish climate system modelling activities, and conducts research on the Earth's atmosphere, as well as near space and solar influence on the planet's atmosphere. Affiliated with FMI is Professor Sergej Zilitinkevich, internationally recognised for his work on atmospheric boundary layers, for which he recently received an

Advanced Investigator Grant from the European Research Council (ERC).

FMI and the **University of Kuopio** are partners at the Finnish Centre of Excellence in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change at the **University of Helsinki**. The centre and its director, Markku Kulmala, are world famous for its research on aerosols. Professor Markku Kulmala is yet another of the Nordic researchers who has received funding from the ERC.

Researchers at the University of Helsinki conduct climate change related research in several disciplines, such as forest ecology and palaeoclimatology. The University hosts, in cooperation with FMI, the project office for the international project “Integrated Land Ecosystem – Atmospheric Processes Study” (iLEAPS). iLEAPS is a core project of the International Geosphere – Biosphere Programme (see Chapter 6).

The **Thule Institute** at the **University of Oulu** operates as a national and international expert institute on Northern and Environmental Issues. Core research themes related to climate change are global change in the North, land use, climate change and resilience, and environmental economics.

The **Finnish Environment Institute** (SYKE) is a research and expert organisation with a focus on environmental changes. Its research covers a range of topics from climate change and declining biodiversity to regional and local environmental issues. SYKE takes a multi-disciplinary approach combining socio-economic research with natural science research. The Institute has been involved in many international projects within impact and adaptation studies, and its research professor Timothy Carter was coordinating lead author for the chapter on “New assessment methods and the characterisation of future conditions” in the IPCCs fourth assessment report, published in 2007.

Iceland

The geography and topography of Iceland makes it an ideal place for various studies aimed at reconstructing the dynamics of past environmental and climatic variability. The monitoring of climate changes and variability is among the primary responsibilities of the **Icelandic**

Meteorological Office (IMO). The office conducts observations of climate change and is involved in modelling and climate change projections in collaboration with the Icelandic **Institute of Meteorological Research** (IMR). The IMO participates in several international climate change projects and has had the coordinating responsibility in Nordic climate change research projects focusing on hydrological and glaciological consequences of climate change, including effects on renewable energy resources.

Paleoclimatological research has mainly been carried out at the **University of Iceland**, which conducts climate-change-related studies within the Institute for Sustainable Development, the Institute of Economic Studies (Energy Economics) and the Institute of Earth Sciences. The latter takes advantage of the special geological features of Iceland for research into glacial processes, ice-volcanic interactions and impacts of volcanic eruption on climate.

In the maritime climate of Iceland, monitoring the oceanic climate and environment is very important. The **Icelandic Marine Research Institute** monitors the physical- and chemical oceanography of Icelandic waters, including ocean acidification. In collaboration with researchers from the **University of Akureyri** and the University of Iceland researchers from the Marine Research Institute have mapped pathways for ocean currents in the northern North Atlantic, and documented changes that influence climate over a large area.

Norway

The **Bjerknes Centre for Climate Research** (BCCR) is a Norwegian Centre of Excellence and the largest climate research centre in the Nordic region. BCCR has several authors in the last IPCC report (2007), with Professor Eystein Jansen as coordinating lead author in the report’s chapter on paleoclimatology. Moreover, BCCR is one of four European centres that delivered full climate scenarios to the IPCC report. Key research areas at BCCR are prehistoric climate variability, recent-day climate changes, ocean, sea ice and atmosphere, ocean carbon cycles, future climate and regional effects. Its geographical focus is on Northern Europe and the polar regions. The centre is coordinated by the **University of**

Bergen in cooperation with the **Institute of Marine Research** and the **Nansen Environmental and Remote Sensing Centre**.

At the **University of Oslo**, several institutes conduct climate change related studies. The Department of Geosciences focuses on the natural science dimension within areas such as atmospheric chemistry, physical oceanography, and ecosystems responses. The University of Oslo also has strategic research collaboration with seven independent research institutes concerning the **Oslo Centre for Interdisciplinary Environmental and Social Research** (CIENS). Climate change research is one central area of cooperation between the partners in CIENS.

The Centre for Development and the Environment (SUM) is a research centre at the University of Oslo that was established as a response to the Brundtland report²³ from the United Nations World Commission on Environment and Development (WCED), published in 1987. SUM and the Department of Sociology and Human Geography are involved in several important research activities within the human and social dimensions of climate change. Associated with the University of Oslo is the independent research centre **CICERO** (Centre for international Climate and Environmental Research), which focuses on climate change science, mitigation and costs, impacts, vulnerability and adaptation, and international agreements and policy instruments.

Polar research is a prioritised area of research in all Nordic countries, and the **Norwegian Polar Institute** in Tromsø is one important centre of research competence in this field. The Norwegian Polar Institute is a directorate under the Norwegian Ministry of the Environment, conducting research on climate changes in the polar regions, as well as the consequences they have for the unique polar environment. The Norwegian Polar Institute recently opened a new **Centre for Ice, Climate & Ecosystems** (ICE).

As in all Nordic countries, the **Norwegian Meteorological Institute** (NMI) is an important centre for competence in the field of climate modelling. Its research within meteorology and oceanography emphasises atmospheric and marine forecasting, climate and environmental studies. NMI is one of the partners in the

Norwegian Climate Centre, which is a formal cooperation between leading climate change research centres in Norway.

Sweden

The world famous professor of meteorology at **Stockholm University**, Bert Bolin (1925-2007), was one of the founders of the IPCC and its chairman from 1988-1997. He has also lent his name to the **Bert Bolin Centre for Climate Research** (BBCC) at Stockholm University. BBCC coordinates the climate research of four departments: (i) Meteorology, (ii) Physical Geography and Quaternary Geology, (iii) Geology and Geochemistry, and (iv) Applied Environmental Science. The focus is on five cross-disciplinary core themes: climate variability, atmospheric and ocean circulation, boundary conditions for circulation system modelling, biogeochemical cycles, and small-scale processes with large-scale impacts. BBCC received the Swedish Linné grant²⁴ in 2006.

Stockholm University also hosts the **Institute for International Economy Studies** (IIES), where research on the economics of climate change is conducted. One of the researchers affiliated with the IIES is Professor Per Krusell, who has received numerous awards and prestigious grants, including an Advanced Investigator Grant from the European Research Council.

Stockholm University is one of the partners behind the **Stockholm Resilience Centre**, an international centre for transdisciplinary research of the governance of social-ecological systems, focusing on the ability to deal with climate change. Another partner behind the Stockholm Resilience Centre is the **Stockholm Environment Institute** (SEI), which is an independent, international research institute dealing with overarching issues such as climate change, energy systems, vulnerability and governance, as well as specific problems such as water resources and air pollution. SEI's work on energy scenarios, sustainability modelling and vulnerability assessments has gained particular recognition at the international level. Climate change adaptation and mitigation is also an important research area at SEI, and Professor Richard Klein was coordinating lead author of the chapter on "Relations between mitigation and adaptation" in the latest IPCC report (2007).

The Environmental Economics Unit at the School of Business, Economics, and Law at Sweden's second-largest university, **Gothenburg University**, is another institute that focuses much of its research on climate and natural resource management, especially in developing countries. Gothenburg University has several faculties and departments conducting and promoting climate-related research, for example, **The Centre of Earth Systems Science** (Tellus), which is an interdisciplinary research programme dedicated to Earth systems science, focusing on climate change impacts on the Baltic environment system and Arctic/Sub-Arctic climate. Moreover, The University of Gothenburg also hosts a **Marine Research Centre** and a **Centre for Environment and Sustainability**, both carrying out climate change research.

At Sweden's largest university, **Lund University**, climate change research is conducted at several faculties and departments. Eleven thematic areas have been identified as relevant for global climate change. These include large-scale climate patterns, atmospheric processes, carbon cycle processes, ecosystems and biodiversity, along with policy and strategy. Two centres where climate change related research is conducted received the Swedish Linné grant in 2008: **The Lund University Centre of Excellence for Integration of Social and Natural Dimensions of Sustainability** (LUCID) and the **Lund Centre for studies of Carbon Cycle and Climate Interaction** (LUCCI).

The **Swedish Meteorological and Hydrological Institute** (SMHI) has played an important role in several ongoing and past climate research projects in Sweden. Research activities are focused on describing and analysing conditions in the atmosphere, lakes, oceans and other watercourses. SMHI and the climate modelling research unit the **Rosby Centre for Climate Change** are important centres of competence contributing to the collective strength in climate modelling of the Nordic countries.

4.3 NORDIC CLIMATE CHANGE RESEARCH PRIORITIES

A long tradition of Nordic collaboration has resulted in many joint initiatives within research funding and research policy. Nordic research funding aims to focus on areas in which the Nordic countries are prominent. It seeks to create synergies that supplement existing national investments in research. Climate change research has been found to be one of the research areas relevant for joint Nordic initiatives. Some of the most eminent joint initiatives, financed by Nordic organisations, are presented below.

The Top-level Research Initiative – a Major Nordic Venture for Climate, Energy and the Environment

In the autumn of 2008, the Nordic countries joined forces on the largest joint Nordic research and innovation initiative to date. The Top-level Research Initiative within climate, energy and the environment will involve various Nordic organisations and national institutions, with a budget of nearly □ 54 million over five years. In addition to being a Nordic contribution towards solving the global climate crisis, the initiative will promote research and innovation within the region. It will focus on fields of climate and energy research of common interest to the Nordic countries, as well as where the region can contribute with international solutions.

The Top-level Research Initiative consists of the following six sub-programmes:

- Effect studies and adaptation to climate change
- Interaction between climate change and the cryosphere
- Energy efficiency with nanotechnology
- Integration of large-scale wind power
- Sustainable bio-fuels
- CO₂ – capture and storage

Within the framework of these six themes, the initiative will also include advanced climate modelling, social sciences and humanities and a focus on the Arctic area. The Top-level Research Initiative will last for five years. The first calls for proposals were published the autumn of 2009.

Impacts of Climate Change in Nordic Primary Industries

Complementary to the Top-level Research Initiative, special attention is given to the threats and possibilities of climate change on primary industries in the programme entitled “Climate Change Impacts, Adaptation and Mitigation in Nordic Primary Industries (Fishery, Agriculture, Food, Forestry)”. This thematic network programme aims to provide the basis of a Nordic climate change adaptation and mitigation policy for natural resources and food production. The purpose is to create Nordic networks focusing on sustainable resource management within five thematic areas:

- Plant and animal health
- Conservation, adaptation and utilisation of genetic resources
- Adaptation and mitigation in milk, meat and cereal production systems
- Impacts and adaptation in fish production systems
- Sustainable biomass production and carbon storage in terrestrial ecosystems

The results of the networks will serve as input to a policy report.

Nordic Centre of Excellence Programme on Global Change

The decision to form a Nordic Centre of Excellence Programme was made in 2001, when the five Nordic countries, the Nordic Council of Ministers and NorFA, the predecessor of NordForsk, agreed to finance jointly a Nordic Centre of Excellence Programme on Global Change. The aim of the programme was to increase the quality, efficiency and visibility of Nordic research; to enhance the competitiveness of Nordic research and strengthening Nordic cooperation; and to support Nordic research to achieve a leading international position. Four centres were financed within the programme in the areas of ecosystem carbon exchange, biosphere–aerosol–climate interactions, ecosystem dynamics and luminescence research. In 2008, the programme ended and was recognised as a success (see page 33).

Nordic Researcher Networks within Climate Change Research

NordForsk annually calls for “Nordic Researcher Networks”. This call is open to all fields, and a part of the funded projects are within climate change research. “Nordic Researcher Networks” bring together prominent research groups in the Nordic countries to strengthen and increase the quality of research and research training at Nordic, European and international levels. Within climate change research, Nordic Researcher Network funding encompasses a wide range of disciplines within ecology, remote sensing, paleo-environmental modelling, paleoclimatology, law and political science, and collaboration between physical, chemical and biological sea-ice research. All networks provide workshops, post-graduate research training and education and allow for mobility of young researchers. The research communities benefit from the Nordic collaboration in the networks through sharing of expertise, data and instruments. A common objective of the networks is to establish permanent collaboration in the Nordic region.

In addition to the initiatives presented here, which are part of formalised Nordic collaborations financed by Nordic organisations, many other platforms for collaboration have been established, as collaborations by industries or research institutes.

EUROPEAN RESEARCH COUNCIL GRANTS TO NORDIC CLIMATE CHANGE SCIENTISTS

The European Research Council (ERC) is the first European funding body designed to support investigator-driven frontier research through open and direct competition. Its main aim is to stimulate scientific excellence in Europe by supporting and encouraging the very best, truly creative researchers to identify and explore new opportunities and directions in any field of research.

The ERC offers two types of long-term grants, the ERC Starting Independent Researcher Grants to support the independent careers of outstanding researchers, who are at the stage of establishing or consolidating their first research teams or programmes, and the ERC Advanced Investigator Grants to support pioneering, frontier research projects by leading established researchers. Below is a list of Nordic ERC-grant winners working with topics that are strongly related to climate change:



Prof. Per Krusell

Stockholm University

Quantitative dynamic macroeconomic analysis of global climate change and inequality; building dynamic quantitative macroeconomic models of the world economy with a climate system as an integral part.



Prof. Kirsten Hastrup

University of Copenhagen

Natural environmental disasters and social resilience in anthropological perspective, with a focus on local and social responses to environmental disasters related to water, spurred by, for example, the melting of ice in the Arctic, rising sea levels and desertification.



Prof. Sergej Zilitinkevich

Finnish Meteorological Institute

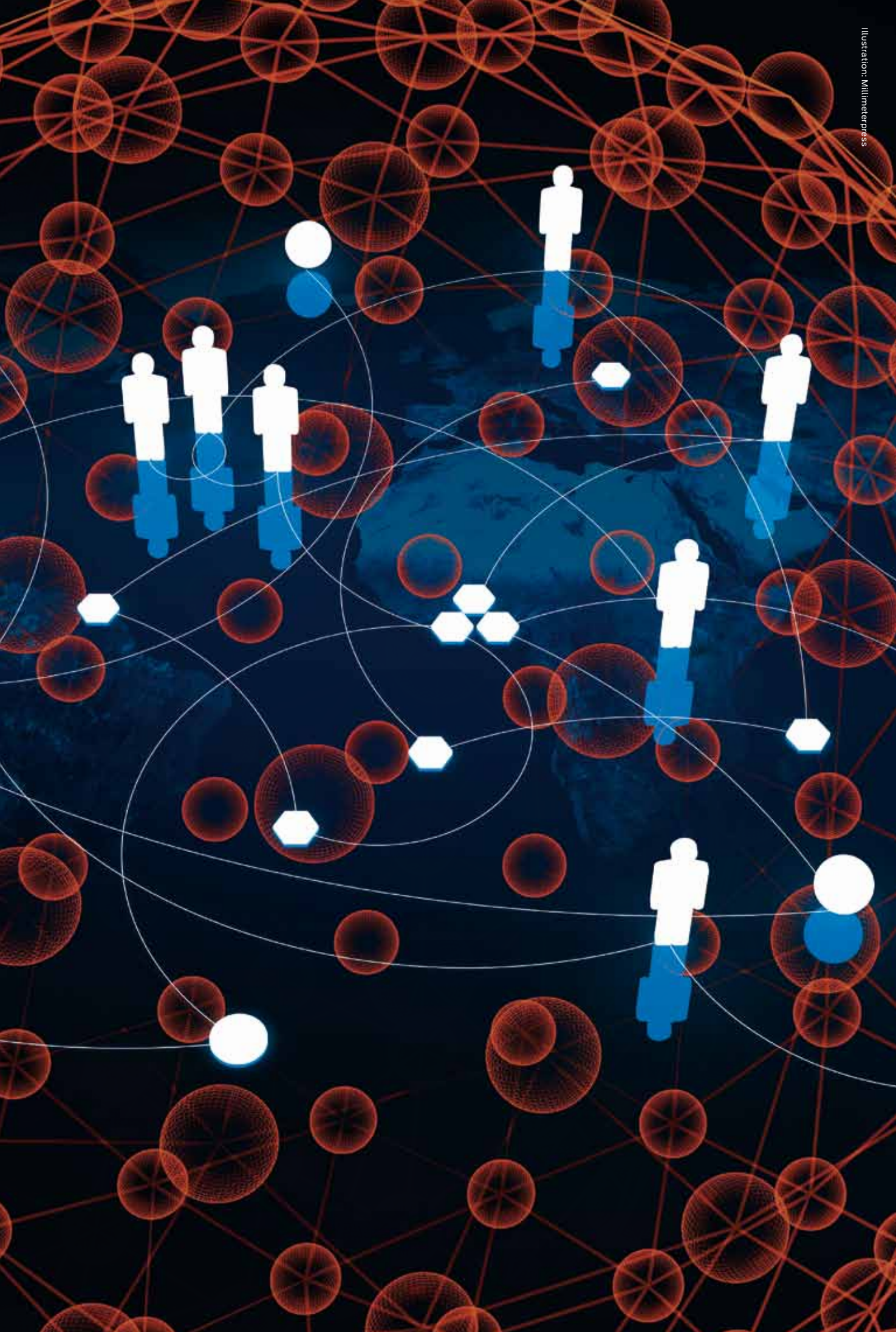
Atmospheric planetary boundary layers, focusing on the key physical problems related to the role of planetary boundary layers in the Earth system.



Prof. Markku Kulmala

University of Helsinki

Atmospheric nucleation: from molecular to global scale; quantifying the mechanisms responsible for atmospheric, new particle formation and investigating how important this process is for the behaviour of the global aerosol system and, ultimately, for the whole climate system.



Nordic Centre of Excellence Programme on Global Change (2003-2007)

Swedish clouds very easily become Finnish rain, Norwegian birds migrate to Denmark with a few wing flaps and an expert in spectroscopy from Norway can easily work in a Danish lab. Ecological and climate-related phenomena do not adhere to political boundaries, and, aided by the first Nordic Centre of Excellence Programme, nor do Nordic scientists in this field.

With many of the same geographical features, similar languages and several shared cultural references, the Nordic countries have always had great potential for efficient collaboration across borders. Now, these neighbouring countries also have several climate problems in common, and there is a great need to work together. But how does one cultivate long and strong Nordic traditions of scientific cooperation in a vast landscape dotted with small, national institutions, each with a limited number of excellent researchers, but with a great common potential?

Reshaping geography

That was the question in 1998, when the members of the Joint Committee of the Nordic Natural Science Research Councils began sketching out an idea for new ways to cooperate among the Nordic countries.

One of the key ideas they came up with was the programme of research cooperation now known, and renowned, as the Nordic Centres of Excellence (NCoE) Programme. However, at that time, it felt like planning a journey without maps.

They were faced with a difficult “topography”. Several good Nordic scientists were

working in the same fields of research, but they were scattered over a large area. Would it be possible to create visible and attractive mountain ranges by connecting these solo peaks?

The Nordic Natural Science Research Councils believed it was.

A comprehensive but remarkably “bottom up” process of discussions and input from all interested parties followed, and, by 2001, the NCoE concept was formalised.

The NCoE concept

The design proposed building each centre as a network around **an innovative, top research community**. Academics from **all levels of expertise** and training were to be involved, and, of course, the **highest possible quality** of scientific research was required.

Two different forms of collaboration were suggested. One type would be the so called “virtual centres”, where researchers would be geographically situated at different institutions, working on common projects. In the other type of centre, a “physical” rather than “virtual” variety, the researchers would all be working together in one place.

To ensure the high quality and efficiency of the research projects, the NCoEs were to be regularly followed up by a **Scientific Advisory Board (SAB)**, consisting of non-Nordic scientific experts.

The National Research Councils, Nordic Council of Ministers and—later—the new Nordic Research Board NordForsk were convinced, and they granted a total of □ 7.5 million in support of a five-year Nordic Centre of

Excellence pilot programme. This money was meant as an addition to the selected research projects' basic funding, which should be acquired before applying for Centre of Excellence status. The Nordic money was purely to function as "glue-money", meant to cover practical costs such as travel expenses for visits and exchanges between participating scientists at all levels of advancement. By the end of the five-year period, the investors hoped to see a "Nordic added value".

The first scientists to explore the ins and outs of this new and complex form of collaboration were top researchers in the area of *global change*.

Why "global change"?

Being a **multidisciplinary field**, in which the Nordic countries had **researchers in the world elite**, and since it was included in the **EU 6th Framework Programme**, *global change* seemed an appropriate terrain within which to perform a thorough test of this new form of collaboration.

Another argument for choosing global change as a topic was the fact that there are **important and unique climatic phenomena present** in the Nordic region that can not be moved elsewhere and that do not adhere to national boundaries. Developing advanced research nodes in relation to these phenomena could prove useful for attracting international attention and expertise to the Nordic and Arctic areas.

The field of global change was narrowed down to three themes that resounded with the research being undertaken in the Nordic countries at the time: **atmospheric research, oceanographic research and ecosystems**.

Through careful selection, three to four transnational networks were to be designated as Nordic Centres of Excellence. An external selection panel reviewed the 18 applications submitted and chose 8 finalists with whom they performed interviews and site visits, before ranking the applications. In the end, four were selected – three of them were "virtual" centres.

The four NCoEs presented in 2002 were:

1. Research centre on biosphere-aerosol-cloud-climate interactions (BACCI)

- administered from Helsinki, Finland, and lead by Markku Kulmala

The BACCI network was already established before they were granted NCoE status, and BACCI utilised this network in their programme.

Their scientific project relies on data from numerous measuring stations – measurements to which they would not have had access without close cooperation across borders. The scientists can measure in much finer scale now than they could at the beginning of the project, and BACCI has grown from a Scandinavian collaboration into a European network.

"A lighthouse of excellence," according to the Scientific Advisory Board, the BACCI project has not only produced a significant amount of papers and PhDs, and positioned itself as a role model for new European programmes, but also impressed by a simple, yet outstanding way of measuring its own success: When the program began, the researchers of the BACCI Centre set up a list of scientific questions to which they wanted to find answers. By the end of the five-year period, all of these questions were answered.

2. The dynamics of ecological systems under the influence of climatic variation (EcoClim)

- administered from Oslo, Norway, and lead by Nils Chr. Stenseth

EcoClim have mapped and studied the effects of climate change on ecosystems – for example, on cod in the Barents Sea and changes in bird migration – both examples of research areas in which international co-operation are essential for collecting data.

While the scientific success of the EcoClim project was never questioned, the Centre had to make an effort to establish good administrative and co-operational procedures after receiving demands for stronger structural control at the mid-term evaluation. Through hard work, the demands were met, and, by the following round of evaluations, EcoClim received very good marks.

3. Nordic centre for studies of ecosystem carbon exchange and its interactions with the climate system (NECC)

- administered from Lund, Sweden, and lead by Anders Lindroth

In terms of visibility, this project has been highly successful. Using advanced, new instruments to measure methane emissions, NECC produced some unexpected and unique scientific results that have generated hundreds of articles and attracted immense international attention.

In Sweden, the NCoE has resulted in a National Centre of Excellence named LUCCI, which involves researchers from an even wider spectrum of disciplines in the study of carbon cycle and climate interactions.

In cooperation with BACCI, NECC also formed the Nordic Graduate School: Biosphere-Carbon-Aerosol-Cloud-Climate Interactions (CBACCI), offering interdisciplinary education for PhD students and Post-Docs.

4. The Nordic centre for luminescence research

- administered from Risø, Denmark, and lead by Andrew Murray

The only physical infrastructure Centre, and the smallest one of the four NCoEs, the Nordic Laboratory for Luminescence Dating in Risø has managed to create a name for itself and thereby attract some of the best young researchers in the world to its visitors' programme. The method of luminescence dating has achieved international recognition in recent years, and the Laboratory in Risø has undoubtedly contributed to this.

The Centre's success in creating and developing portable luminescence measuring units has truly put Risø on the international map within this field of expertise.

The explorers drew the map

Eight years after they started out, the parties involved in the pilot programme are no longer talking about whether the NCoE concept is a good idea; the Nordic Centres of Excellence have been unanimously deemed successful, both by the participants and their advisers, as well as the evaluation panel.

Through hard work, some wrong turns, but generally a good and steady pace, all four centres had found the way to their scientific destinations in good shape. By joining forces, some of the best, yet geographically dispersed, scientists in the Nordic nations were indeed able to create a **"Nordic added value"**. Many small research communities working together on common projects improved their visibility and strengthened their international competitiveness. As Nordic Centres of Excellence, they had become more attractive for international expertise, and the programme did make it easier to promote the mobility of the Nordic researchers involved.

Climate change challenge remains

However, while five years of the NCoE-program in the field of global change had been fruitful, the problems and challenges of research on *global change* are hardly over. More expertise, collaboration and funding is certainly needed to keep Nordic excellence in global change vital, and a mere five years of Nordic support might not be enough time for the Centres of Excellence to become truly prominent in an international context. Prolonging the time span that the centres can carry their label of "Nordic Excellence" has been suggested as a possible programme improvement.

For, despite the actual monetary value of the Nordic support being low, the Global Change NCoEs have proved that, **when utilized correctly, a little money goes a long way.**

And, it has not gone unnoticed: the way scientists see funding size as a direct measure for prestige appears to be changing. It seems **money is no longer the main incentive** for becoming a Nordic Centre of Excellence. As the first party out, the NCoEs on Global Change managed to tread a path and create a "brand" that has a value in itself. The NCoE "prefix" has become a label even wealthy projects desire, not solely for the money, but more importantly for the **prestige, networking opportunities, and improved prospects for future financing** that result from being selected as a Nordic Centre of Excellence.



5. Research Focus in the Nordic Countries

Nordic research covers a broad range of topics relevant to climate change – including fundamental climate science and the impacts of a changing climate on society and environment, as well as the tools and approaches for dealing with the challenge of climate change. In the following sections, we present an overview of climate change research in the Nordic countries, using the IPCC framework (see Chapter 3.1).

■ Climate change - How is the climate changing?

Under the general heading of climate change the key questions are how the climate is changing and how it has been changing in the past; i.e., where temperatures are rising and how that influences ocean currents, patterns of precipitation and winds, the extent of sea ice and glaciers, etc.

■ Climate change drivers - Why is the climate changing?

This section covers research on the causal factors behind climate change, both man-made processes and natural variability. This includes studies of the carbon cycle and feedback mechanisms, the role of greenhouse gas emissions, aerosols, and land-use changes. Moreover, drivers like solar variability and volcanic eruptions fit under this heading.

■ Impacts and vulnerabilities – What are the consequences of climate changes?

This section covers research on the effects of climate change in nature and society: What are the consequences for flora and fauna and ecological systems? Also, what are the positive and negative consequences for habitation, agriculture and health?

■ Adaptation and mitigation – What are appropriate responses to climate change?

This section covers research on how we can mitigate and adapt to climate change. This includes how societies can reduce concentration of greenhouse gases in the atmosphere and how to limit the negative effects of actual or expected climate change. Although adaptation studies often focus on risk management, it also addresses the question of how to harvest opportunities from climate changes. As explained in the introductory section, this publication does not cover mitigation by technological research within energy, industrial production or waste.

There is a vast amount of research topics and projects that potentially fits within this scope. Although it is our ambition to cover a wide range of climate change research areas, the scope of this publication does not allow us to include all relevant activities. Instead, we present the reader with a brief description of a selection of research activities at Nordic universities, research institutions and centres, with the intent of illustrating important research themes in the Nordic countries. This includes, for example, areas where there are Centres of Excellence, where Nordic researchers are well represented or have leading roles in international projects, or where Nordic researchers have made important contributions to international reports (such as IPCC). We mainly highlight ongoing, larger multiparty projects, but some recently finalised projects are also included, as they describe important results and background for current activities. We recognise that important and relevant climate change research is also conducted outside of the research areas highlighted in this report.

Nordic participation in EU-funded projects is extensive, and as the EU is an important source of funding for multiparty projects involving Nordic researchers, many of the projects described in the following sections are funded by EU's Framework Programme for Research and Technological Development. Other international projects are described when they illustrate Nordic research focus and/or excellence. Some of these activities are also mentioned in Chapter 6 and 7, as examples of Nordic participation in international research cooperation or of climate change research relevant to developing countries.

We find the framework of IPCC, outlined above, useful when describing Nordic climate change research. However, due to the interdisciplinary nature of climate change research, any attempt to structure the information is a challenge. Vulnerability cannot be assessed and adaptation cannot be developed without an understanding of impacts, which in turn requires an understanding of climate change itself. Consequently, many research programmes and larger projects cover a wide array of topics within one single programme, and they search for interrelationships between these domains.

” SYSTEMATIC OBSERVATIONS AND MONITORING OF CLIMATE PARAMETERS AND ENVIRONMENTAL CONDITIONS ARE THE BASIS FOR UNDERSTANDING HOW CLIMATE IS CHANGING.

5.1. CLIMATE CHANGE - HOW IS THE CLIMATE CHANGING?

In recent decades, important progress in understanding how the climate is changing has been achieved through improvements and extensions of numerous datasets and data analyses, broader geographical coverage and a better understanding of uncertainties. Although climate change is dependent on many processes that climate models today are unable to describe in detail, it is now possible for climate scientists to monitor, simulate and project global climate with increasing accuracy.

When it comes to research in the phenomena of climate change, Nordic countries have especially strong research groups working with climate models, understanding climate change in the Arctic and Nordic regions and research within the field of paleoclimatology. In the following sections, we highlight examples of Nordic research under the headings of climate change monitoring and observations, paleoclimatology and climate modelling.

Climate Change Monitoring and Observations

Systematic observations and monitoring of climate parameters and environmental conditions are the basis for understanding how climate is changing, as well as for impact assessments. Relevant data is collected by means of satellites, weather balloons, measuring and field stations, as well as during prolonged field expeditions. For ocean monitoring, observations are made *in situ* from ships, buoys or offshore installations and from satellites.

The Nordic countries have a long tradition of climate and environmental monitoring, with long-time series that play an important role in climate change research. Extended time-series from Greenland, Iceland and Norway, including Svalbard and Jan Mayen, are valuable for understanding climate variability in the Arctic and sub-Arctic. Some time series from Nordic locations are among the oldest in the world, beginning in the early 18th century. One example is the North Atlantic Oscillation (NAO) index, which is based on observations from Iceland and Portugal, starting in the early 19th century.

The Nordic meteorological institutions play a key role in monitoring climate changes and operating databases, but other institutions, such as institutes for environmental, marine, air and geological research, also make important contributions in this field. Nordic countries send observation data from their respective territories to the global observation systems for climate, and they participate in projects aiming to improve observation and monitoring of parameters relevant for climate change research. Nordic research institutions are, for example, part of international efforts for developing the observational capabilities for greenhouse gases. The “Integrated Carbon Observation System” (ICOS)²⁵ aims to develop a European research infrastructure dedicated to high precision observations of greenhouse gas fluxes, integrating ecosystem and atmospheric observations. Research institutions from Finland, Denmark, Sweden and Norway are partners involved in this effort, which is in a pre-project phase.

The project “Global Monitoring for the Environment and Security” (GMES) is a European programme for the implementation a European capacity for Earth observation. In 2008, GMES pre-operational services were launched, with the objective to move into the operational phase in 2011. The setting up of these pre-operational services has been assigned to projects financed through the EU Framework Programmes for Research and Technological Development. “MyOcean” is one such project. Its activities are based on the combination of space and *in situ* observations and the use of 3-D assimilation models. Nordic participation is significant, with one Swedish, two Finnish, four Norwegian and four Danish partners.

Ocean observations and monitoring are important contributions of Nordic institutions to the field of climate change research. Due to the geographical position of the Nordic countries and their interests in the fishing industry, climate-related processes in the oceans is a research topic in several former and current projects. Oceanographic data such as sea level, ocean currents, sea-ice, surface temperature, CO₂ concentration and salinity is mainly

collected and managed by meteorological and marine institutes in the Nordic countries. Nordic ocean monitoring also includes the observation of biological and ecological parameters related to climate change impact studies, which is an important area of research at several Nordic universities as well. The fact that oceanography is a strong research field in the Nordic countries is manifested, among other things, by the Nordic presence in international projects. For example, two Norwegian centres coordinate international projects including elements of observation; the Bjerknes Centre for Climate Research manages the project "Bipolar Atlantic Thermohaline Circulation" (BIAC) and the Nansen Environmental and Remote Sensing Centre is responsible for coordination of the EU project "Acoustic technology for observing the interior of the Arctic Ocean" (ACOBAR).

ACOBAR is funded by the EU 7th Framework Programme for Research and Technological Development (FP7), and it involves eight other international partners. During the project period 2008-2012, the project will develop an observing system for the interior of the Arctic Ocean based on underwater acoustic methods, contributing to filling gaps in the global ocean observation system.

The BIAC project is one of the larger projects initiated within the framework of the International Polar Year (IPY). One of the objectives for the project is to establish monitoring stations that can help researchers to understand the role of the thermohaline circulation²⁶ as a driving force for ocean circulation and global climate.

Nordic researchers are also strongly involved in improving capacities for monitoring and observation in the Arctic area. "Sustaining Arctic Observing Networks" (SAON) is a major initiative with Nordic participation. SAON was initiated by the Arctic Council and continued within the International Polar Year, as a process to further multinational engagement in developing sustained and coordinated pan-Arctic observing and data-sharing systems. Nordic countries are also involved in the EU-funded "Developing Arctic Modelling and Observing Capabilities for

Long-term Environmental Studies" (DAMOCLES). The Norwegian Meteorological Institute and the Swedish Meteorological and Hydrological Institute are co-leaders in the projects.

Much could be written about infrastructure and systems for observation in the Nordic countries, but we have chosen to highlight Nordic research stations in the Arctic, where important monitoring and observational studies are carried out. Ny-Ålesund in northwestern Svalbard is home to many international research stations. Two of them are operated by the Norwegian Polar Institute: the Sverdrup Research Station and the Zeppelin Research Station.

At the **Sverdrup Research Station**, monitoring of polar climate, glaciers and ice are among the topics of primary interest. Long-term monitoring programmes of basic meteorological data, solar radiation, surface albedo and spectral reflectance are continuously performed at the station. Biological studies at the Sverdrup Research Station include monitoring of reindeer, arctic foxes, polar bears and marine mammals and birds. At the **Zeppelin Research Station** nearby, the Norwegian Institute of Air Research performs atmospheric research on a global scale. The Institute has measured the concentration of a large number of greenhouse gases since 1989. The station is also basis for measurements of CO₂ and particles carried out by the department of meteorology at Stockholm University.

The Norwegian Polar Institute also operates a research station in the Antarctic, called Troll. It is a meteorological station that measures UV radiation, as well as a field station for glaciological, biological and physical field programmes.

Another high-Arctic research infrastructure is the **Zackenbergl Research Station** in North-East Greenland, operated by the Danish National Environmental Research Institute (NERI) at Aarhus University. It is an ecosystem research and monitoring facility, where the research programme were initiated in 1995 and fully implemented for the terrestrial part of the ecosystem in 1996. During subsequent years, the basic terrestrial programme has been supplemented with programmes for other parts of the Arctic environment, such as



FIGURE 4: Map over Nordic research stations in the Arctic region

marine environment and glaciers.

Further south in the Arctic area, Sweden hosts two scientific stations also relevant for climate change observation. The Royal Swedish Academy of Sciences operates the **Abisko Scientific Research Station**, situated on the southern shore of Lake Torneträsk. The main focus areas of the meteorological projects are recent climate changes in the region and local variations of the microclimate in sub-alpine and alpine ecosystems. Plant ecology is also an important research area at the station.

Situated at the eastern hills at the highest mountain in Sweden, Kebnekaise, the **Tarfala Research Station** is a base for measurements and monitoring of glaciers, meteorology, hydrology, snow and permafrost. Stockholm University manages this research station. The origin of the activities at Tarfala was the mass balance monitoring programme of the glacier Storglaciären. The programme started in 1946, and the series is now the world's longest continuous series of measurements using the so-called Scandinavian method, which involves measuring both the total mass added in the form of snow during winter and

the total mass lost through melt during the following summer²⁷.

In northern Finland, the **Arctic Research Centre (ARC)** of the Finnish Meteorological Institute is located at Sodankylä in Finnish Lapland. The ARC and the **Pallas Atmospheric Research** station, situated 125 km away, conduct atmospheric measurements. At the observatory at Sodankylä, focus is on upper-air soundings, synoptic measurements, and ozone observations, while Pallas-based observations focus on the tropospheric air composition and related boundary layer. Research infrastructure at Pallas includes the Pallasjärvi Research Forest and Lake Pallasjärvi catchment research area. The Pallas station is part of the "Global Atmosphere Watch" (GAW) that reports on global greenhouse gas concentrations.

FEATURED SCIENTIST: JØRGEN PEDER STEFFENSEN

Looking to the past to predict the future

“The Greenland ice is a unique archive for atmospheric conditions” Jørgen Peder Steffensen of the Niels Bohr Institute, Copenhagen University, explains. “As Greenland never experiences thaw, the snow that falls becomes a big layer cake where each layer represents summer and winter seasons and gives unparalleled information about past weather conditions”.

Jørgen Peder Steffensen took a four-year leave of absence to run the Carlsberg Dating Initiative from 2002-2006 and is Associate Professor at the Niels Bohr Institute and Chief Logistics Coordinator of the “North Greenland Eemian Ice Drilling” project (NEEM). The NEEM project is coordinated by the Centre for Ice and Climate at Copenhagen University and seeks to retrieve ice from the previous interglacial to obtain information about past temperatures and the levels of greenhouse gases in the atmosphere. Fourteen nations participate in the project, with Denmark financing 50 percent of the budget.

During the field season in 2009, the NEEM team spent a successful four months drilling

in the Greenland ice sheet. “This was our second year of drilling and we have reached 1765 meters down into the ice. The goal is to drill through the more than 2.5 km deep ice by the end of next year’s season, as that will give us leeway to do some additional exploration” he continues. The NEEM project has two more

years’ worth of funding, but Steffensen believes that the drilling activities will be continued. “The information we obtain from these ice cores are imperative to climate change research and modelling. Our studies show that the ice age ended in exactly one year – it would be extremely difficult for society today to adapt to such rapid changes in climate and weather conditions”.

In addition, Steffensen explains that, by studying the Greenland ice, they can observe the atmosphere before any climate changes took place, thus deciding whether climate change or greenhouse gases came first. “For the last 10,000 years the climate has been remarkably stable, but what if we are now pushing the climate out of this stable form?” Steffensen proposes, leaving the million dollar question hanging in the air.

FOR THE LAST 10,000 YEARS THE CLIMATE HAS BEEN REMARKABLY STABLE, BUT WHAT IF WE ARE NOW PUSHING THE CLIMATE OUT OF THIS STABLE FORM?



Paleoclimatology – Climate Changes in the Past

Records of past climate change from observations generally cover up to 150 years. To examine the full range of climatic variability, it is necessary to examine climate change going back hundreds and thousands of years, using paleoclimatological records from ice cores, glaciers, trees, corals, sediments and other natural sources. These long-time series of data can demonstrate relationships between natural events and changes in climate and environment that will help scientists to understand current changes in climate—for example, the sensitivity of climate to human influence.

There is an abundance of natural archives in the Nordic region, such as lakes that are rich in layered sediments, very old tree trunks near the northern tree line and ice in the Arctic, that provide many opportunities for research on past climate variability. As a result, tapping terrestrial, marine, and ice core archives to provide high temporal and spatial resolutions of past climates is a major task shared between the Nordic countries.

Especially well known for its paleoclimatic studies is the Centre for Ice and Climate at the University of Copenhagen. Researchers at the centre carry out cutting-edge science within their activities related to the drilling of ice cores through the Greenland ice sheet. These ice cores provide a comprehensive history of climate with high resolution, and they document the full dynamics of the coupled atmosphere-ocean-ice system. The data is used to develop models to explain observations and to predict the ice sheet response to climate change. The Centre for Ice and Climate is a focal point for the international activity for a deep drilling project initiated in 2007, “The North Greenland Eemian Ice Drilling” (NEEM). Research results include new findings about abrupt climate change in history, indicating that changes in the CO₂ levels in the atmosphere can be part of the explanation behind dramatic climate changes. Several Danish institutions, as well as universities in Sweden, Norway, Iceland, Canada and Japan, collaborate with the Centre for Ice and Climate.

The study of lake sediments to reconstruct

past climate change is also conducted by several Nordic research groups focusing on paleoclimatic and paleoecological studies. Many previous projects in this area have drilled for and/or analysed lake records to investigate climate and ecological changes. One example of an ongoing project, which started in 2008, is the study of biological lake sediment data, performed by the Environmental Change Research Unit (ECRU) at University of Helsinki, within the project “Climate Variability in NW Europe During the Past 4000 Years and its Ecological Consequences” (CLIM-ECO).

Seabed drillings are another important contribution to palaeoclimatic records. During the last decade, a large number of North Atlantic paleoclimatic marine studies have been performed by the “International Marine Past Global Changes Study” (IMAGES) community with participation from the Nordic countries. The objective of IMAGES is to collect and interpret high-quality paleoclimatic data from the global oceans. These studies have provided evidence for rapid changes in ocean thermohaline circulation and surface ocean temperatures at regional and global scales in the past. IMAGES is an international collaborative science initiative under the project “Past Global Changes” (PAGES)²⁸ which is an international effort to coordinate and promote past global change research.

An ongoing international project led by the Bjerknes Centre for Climate Research collects deep-sea sediments to improve the understanding of the couplings between the tropics and North Atlantic region. The project is called “Response of Tropical Atlantic Surface and Intermediate Waters to Changes in the Atlantic Meridional Overturning Circulation” (RETRO). The project runs until 2010 and is a cooperative effort among the Bjerknes Centre for Climate Research and partners in Brazil and Europe.

A variety of dating methods are being used in paleoclimatic research and the Nordic Centre for Luminescence Research in Denmark, focusing on luminescence dating, is particularly worth mentioning. It is the only one of its type in the Nordic region, and it is unique in the world in its wide range of activities. At the Centre, the great majority

” THERE IS AN
ABUNDANCE
OF NATURAL
ARCHIVES IN
THE NORDIC
REGION.

of the dating output is used to improve our understanding of the evolution of Late Quaternary climate in collaboration with Nordic geoscientists. The Centre was one out of four centres of excellence in the Nordic Centre of Excellence Programme on Global Change and ran from 2003 to 2007.

Climate Modelling – Predicting Future Climate Changes

High-quality input data from observations and paleoclimatic studies are essential to evaluate past and current trends in the climate system, and a history of data is also necessary to make high-quality projections of the Earth’s future climate.

The science of climate modelling has matured over the last decades through finer spatial resolution, the inclusion of a greater number of physical processes and comparison to a rapidly expanding array of observations. Ever more components have been added to the climate models, including processes related to land, the oceans, the cryosphere and atmospheric chemistry. Consequently, climate models today can predict climate at an unprecedented accuracy. However, there are still important elements of uncertainty in climate modelling, for example, regarding cloud feedbacks, aerosol-cloud interactions, feedbacks related to ice and snow and climate sensitivity.

Advances in modelling have led not only to improvements in complex models combining atmospheric and oceanic processes for projecting 21st century climate, but also to the implementation of so-called Earth System Models of different complexity for millennial time scales. Regional models have also been developed for a more detailed study of regional climate change. Output from these global and regional models is increasingly used as basis for adaptation and mitigation strategies. For adaptation purposes, climate modelling informs different stakeholders about expected climate changes, and climate models are also used in scenarios to illustrate the consequences of different mitigation strategies and emission scenarios.

Nordic meteorological institutes were pioneers in downscaling global climate simulations to regional models, and the collective Nordic

research community holds world-class excellence within the field of climate modelling.

The Nordic countries have some of the most advanced regional climate models in the world²⁹, and several modelling projects in the past have produced climate scenarios that have provided important input to the process of developing national adaptation strategies. Nordic universities and research institutes have also played an important role in several international modelling activities. For example, the Danish Meteorological Institute was coordinating the large-scale EU project “Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects” (PRUDENCE), funded under the EU 6th Framework Programme (FP6) in 2003-2007.

PRUDENCE provided a series of high-resolution climate change scenarios for 2071-2100 for Europe, giving important input to studies on expected impacts of climate change on ecosystems and economy. Another modelling project funded by the EU, running until the end of 2009, is the “ENSEMBLE-based Predictions of Climate Changes and their Impacts” (ENSEMBLES). Nordic countries are well represented by the meteorological institutions in Denmark, Finland, Norway and Sweden, as well as by the Finnish Environment Institute, the University of Oslo, Lund University, Aarhus University and the Nansen Environmental and Remote Sensing Centre. Since 2004, the project team has worked to develop a common forecast system for use across a range of timescales and spatial scales. ENSEMBLES also covers various climate process and impact studies, with the aim of producing integrated scenarios of future climate change and impacts.

Many of the previous Nordic climate modelling activities have had a strong focus on regional climate predictions, aiming to support studies on impacts and adaptations. However, Nordic countries also host strong research groups on global climate modelling. Nordic scientists contribute to the development of Earth System Models (ESM) in several arenas. In Norway, leading climate change research institutions are cooperating on developing a Norwegian ESM in the NorClim project (see below). On the

European level, the “EC-EARTH” project is managed by a consortium representing ten countries, including the meteorological institutes in Denmark, Norway and Sweden as well as two Swedish universities. The goal of EC-EARTH is to build a complete Earth system simulation capacity from the ECMWF coupled model system³⁰ and use it for decadal and longer time-scale integrations in support of IPCC assessment reports³¹.

Climate modelling is also a central element in many of the ongoing interdisciplinary projects mentioned elsewhere in this publication. For example, the Swedish programme Mistra-SWECIA includes a climate modelling module that focuses on contributions to the development of both global and regional earth system models. The Norwegian NorClim project, which is the single biggest national climate change research project in Norway, uses modelling to provide new regional climate scenarios for Norway for the periods 2030 and 2100.

5.2. CLIMATE CHANGE DRIVERS – WHY IS THE CLIMATE CHANGING?

Observations conclude that the climate is changing; global air and ocean temperatures are increasing, there is widespread melting of snow and ice and the sea level is rising. The drivers behind these changes can be divided into anthropogenic (man-made) processes on one hand and natural climatic changes on the other. Scientists agree that both human and natural sources affect the climate, but, as IPCC concluded in 2007, based on the evaluation of a large number of scientific reports, most of the observed increase in global average temperature since the mid 20th century is “very likely” to be man-made due to the increase in anthropogenic greenhouse gas concentration in the atmosphere³².

In addition to studies related to the carbon cycle, including greenhouse gas emissions, research in the area of climate change drivers includes various ocean and atmospheric processes, feedback mechanisms and natural drivers of climate change. In this section, we focus on two areas where Nordic contribution to international research is particularly strong: atmospheric research, including aerosols, and the carbon cycle.

RESEARCHERS
STUDY HOW
PARTICLES ARE
FORMED AND
GROW, STARTING
AT THE
MOLECULAR
LEVEL AND
ENDING UP WITH
PREDICTIONS ON
A WORLDWIDE
SCALE.

Nordic Excellence in Atmospheric Research

Atmospheric chemistry is an important research area at several universities and research centres in the Nordic countries. At the University of Helsinki, the division for Atmospheric Science hosts the Finnish Centre of Excellence in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change, which also involves the Finnish Meteorological Institute and the University of Kuopio.

Research at the centre aims to reduce the uncertainties related to the impact of aerosol particles on climate change. Aerosols are microscopic particles suspended in the Earth's atmosphere. Volcanic eruptions and grassland fires are examples of natural sources of aerosols in the atmosphere, while human sources of aerosols include industrial emissions of gases such as sulphur and nitrogen oxides. The Finnish research centre focuses particularly on the interactions between aerosol particles, clouds and climate. For this purpose, researchers study how particles are formed and grow, starting at the molecular level and ending up with predictions on a worldwide scale. Another major focus of research is the investigation of how biological processes and the biogeochemical cycle impact aerosol particles and atmospheric trace gases. The director of the centre, Professor Markku Kulmala, was also directing the Centre on Biosphere-Aerosol-Cloud-Climate Interactions (BACCI), which was funded by the Nordic Centre of Excellence programme in 2003-2007. Moreover, professor Kulmala has received funding from the European Research Councils (ERC) Advanced Investigator Grant for studies on aerosols and climate change, as mentioned previously.

Professor Sergej Zilitinkevich, who is affiliated with the Finnish Meteorological Institute, received an ERC grant for the project "Planetary Boundary Layers – Physics, Modelling and Role in Earth System". Professor Zilitinkevich is one of the creators of the modern theory of planetary boundary layers, conducting research with applications to pollution-dispersion, weather and climate modelling. His new project on planetary boundary layers also involves the division for Atmospheric Sciences at the University of

Helsinki and Nansen Environmental and Remote Sensing Centre in Norway.

Significant competence within research in atmospheric composition and processes can also be found at several other universities in the Nordic countries, many of whom participate in the European network project “**Atmospheric Composition Change – the European Network of Excellence**” (ACCENT). This network initiates many activities aiming to establish Europe as an international leader in atmospheric composition change.

Two EU-funded projects focusing on atmospheric chemistry and local air pollution in major cities are coordinated by the Norwegian and Danish meteorological institutions. “Megacity—Zoom for the Environment” (CITYZEN) aims to analyse the impacts of air pollution hot spots on regional and global air quality, including potential future changes for various climate scenarios. The other project “Megacities: Emissions, Urban, Regional and Global Atmospheric Pollution and Climate Effects, and Integrated Tools for Assessment and Mitigation” (MEGAPOLI) investigates the interactions among megacities, air quality and climate. Both projects run until 2011.

Carbon Cycle Research

Research on land and ocean carbon cycles relates to the magnitudes and distributions of carbon sources and sinks, the fluxes between the terrestrial, oceanic and atmospheric carbon reservoirs, as well as the underlying mechanisms involved. These are important research themes at several Nordic university departments and research centres. Research focus has first and foremost been on carbon cycles related to areas of special importance for the Nordic countries, such as forests, agriculture, peatlands and oceans.

A large number of past and current projects in the Nordic countries address greenhouse gas emissions and sinks, but in this section we will focus on the most recent projects and where cooperation between the Nordic countries is most significant. In 2003, Nordic research expertise related to the carbon cycle joined forces in the “Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate” (NECC). The centre

was funded as part of the Nordic Centres of Excellence Programme 2003-2007. It was a virtual centre of 14 research groups from institutes in Denmark, Iceland, Sweden and Finland, with the goal to obtain a better understanding of the factors regulating the carbon balance of typical sub-Arctic and boreal ecosystems. This work is continued through the research network NORDFLUX in 2009-2011. Another Nordic initiative is the “Centre of Advanced Forest Research on Environmental Services” (CAR-ES), where research groups from all the Nordic countries and the three Baltic States are working on integrated research that involves how forest land-use affects greenhouse gas emissions, water issues and biodiversity.

Nordic researchers also contribute to international projects addressing the carbon cycle. The two large-scale, EU-funded projects CARBOOCEAN and CarboEurope are important examples with Nordic participation. Recently, the two projects published a joint report, which provided important information about the quantitative role of the oceans and the land surface in the carbon balance of Europe³³.

The CARBOOCEAN project, also known as the “Marine Carbon Sources and Sink Assessment”, focuses on the Atlantic and Southern Oceans. Data and model evaluation was not completely finished when the report was published³⁴, but findings thus far confirm that North Atlantic and Southern oceans carry significant amounts of anthropogenic carbon. Research results also indicate that climate change and rising CO₂ concentrations in the atmosphere and ocean will gradually reduce the oceans’ ability to keep up with additional greenhouse gas loads. This will lead to a gradual decrease in the sink efficiency of the ocean and thus a temporary “huge increase” in the rate of growth of atmospheric CO₂.³⁵

The CARBOOCEAN consortium consists of 47 international groups that began joint research activities on the marine carbon cycle in 2005. Nordic researchers make important contributions, not least through the Bjerknes Centre for Climate Change Research, which is coordinating the project.

The CARBOEUROPE project, also known as the “Assessment of the European

’ ABOUT 80 PER CENT OF THE CONTINENTAL FOSSIL FUEL EMISSIONS REMAIN IN THE ATMOSPHERE AND CONTRIBUTE TO GLOBAL WARMING.

“Terrestrial Carbon Balance”, concludes that there are substantial seasonal and inter-annual variations in several key processes that determine the carbon sink of Europe. For example, when analysing the carbon balance in the dry year of 2003, scientists found that, due to extreme summer heat and lack of rainfall, the European land surface became a source of CO₂, rather than a CO₂ sink³⁶. The carbon balance assessment report also shows that about 80 per cent of the continental³⁷ fossil fuel emissions remain in the atmosphere and contribute to global warming. For the 25 member states in the EU that were included in the study, about 90 percent of the emissions remain in the atmosphere. Moreover, the report concludes that the mitigation potential of the terrestrial vegetation is not realised because of the greenhouse gas emissions by intensive agriculture. European agriculture, both arable and animal husbandry, is only a minor source of CO₂, but a major source for other greenhouse gases.³⁸

Nine research institutes from Denmark, Finland and Sweden were partners in the CarboEurope project, and several of these institutes now participate in a related project: “Quantifying the carbon budget in Northern Russia: past, present and future” (CARBO-North).

Controversial Research about Solar Influence

Research into processes that have an impact on climate change also includes studies about the influence of the sun on global climate changes. The impact on solar variability is disputed and Danish researchers at the centre for Sun-Climate Research at the Technical University of Denmark have attained international attention for their theories about how solar radiation affects the Earth’s cloud cover and climate changes. While these researchers argue that solar variability is a major reason for current climate changes, a majority of the climate research community (and the IPCC) believes that solar changes cannot explain the rapid warming the Earth has experienced over the last decades.

FEATURED SCIENTIST: MARKKU KULMALA

Time-series measurements and understanding climate change

“In short”, explains Markku Kulmala, “the focus of my research is to reduce scientific uncertainties regarding climate change, particularly related to aerosols and clouds”.

Markku Kulmala has been studying atmospheric, new particle formation for 20 years, so his knowledge of the subject is extensive. Being a renowned and quoted scientist worldwide he also has the merits to prove it.

Kulmala became a professor at the University of Helsinki, Finland, in 1996 where he commenced a 5-year Academy Professorship in 2004. He was appointed the Director of the Finnish Centre of Excellence (Physics, Chemistry and Biology of Atmospheric Composition and Climate Change) as well as the Director of the Nordic Centre of Excellence

(Biosphere, Atmosphere, Cloud and Climate Interactions) and has received numerous awards and grants, most recently the Wilhelm Bjerknes medal in 2007 and an ERC grant in 2008.

When Kulmala first set out to study aerosols his work was mainly theoretical on new particle formation. However, in 1996 he began his first continuous atmospheric measurements, which

have lead to the longest time-series observations in the world.

“These time-series observations have been crucial for understanding how new particles are formed” says Kulmala. One of the key findings is that the formation of new nanometer sized particles in the atmosphere occurs frequently and is a global phenomenon. Earlier, it was believed that particle

formation was a rare event and one implication of these findings is that Kulmala and his team may be able to reduce the scientific uncertainties related to climate change and aerosols and clouds. “The Nordic countries are positioned for unique measurement spaces, but there is too little coordination and co-operation between the

countries. We need more cooperation through designated funding for more continuous and comprehensive studies”.

The ERC funding, according to Kulmala, is a good start; it gives a good base for continuing the ongoing research as well as providing him with an opportunity to try out new ideas. These ideas, however, will remain a well-kept secret for now.

THE NORDIC COUNTRIES ARE POSITIONED FOR UNIQUE MEASUREMENT SPACES, BUT THERE IS TOO LITTLE COORDINATION AND CO-OPERATION BETWEEN THE COUNTRIES.



5.3. IMPACTS AND VULNERABILITIES – WHAT ARE THE CONSEQUENCES OF CLIMATE CHANGE?

Climate changes have an impact on animal and plant life, and research has attempted to reveal the extent and distribution of the effects at organism and ecosystem level. The same holds for the direct and indirect impacts on society; water supply and food security are at risk of being severely affected in certain regions. Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems, and climate change has the potential to considerably impact several economic sectors, such as energy supply (for example hydropower), agriculture, tourism, fishing and the forest industry.

The vulnerability of societies to a changing climate is a function of exposure to climate factors, sensitivity to change and capacity to adapt to that change. Systems that are highly exposed, sensitive and less able to adapt are consequently more vulnerable. Research on expected impacts on climate change will facilitate adaptation and may contribute to minimising costs and damages from these changes. In contrast, it can also reveal opportunities that may arise from a change in climate.

Future impacts of climate change, and the vulnerability to those changes, will vary between geographical regions, and even within nations, depending on environmental as well as social conditions. While some areas will experience increased risk for flooding, others can expect reduced access to fresh water due to drought. According to climate model projections for Europe, the average temperature increase is likely to be higher in Europe than the world average, with the highest temperature increases in the northern and eastern Europe.³⁹

Climate Change Impact on Biodiversity and Ecosystems

Many ecosystems are already under pressure due to an unprecedented combination of climate change, associated disturbances (such as flooding, drought, wildfire, ocean acidifica-

tion), and other global change drivers such as land-use change and over-exploitation of resources.

Temperature increase is expected to lead to a shift of climate zones in both altitude and latitude in the Nordic countries and higher temperatures have the potential to affect a number of different plant physiology processes, which in turn govern the structure and function of entire ecosystems. In the northern parts, the decrease of ice and snow cover will impact certain species. Climate change may therefore result in substantial changes in wildlife and vegetation in the Nordic region, but the adaptive capacity of species and ecosystems will decide to what extent this will result in a loss of biodiversity. The immigration of new species may have unpredictable effects on ecosystems.⁴⁰

Several national research centres for the environment and life science departments at the Nordic universities focus on how climate changes affect different species, biodiversity and ecosystems. Ecosystem modelling and studies of ecological responses to climate change in the past in order to better understand impacts of environmental changes in the future, are also important research areas. Nordic researchers were partners in an EU-funded project that ended in early 2009, “Assessing Large Scale Environmental Risks for Biodiversity with tested Methods” (ALARM). The climate change module of ALARM was headed by Lund University, where ecosystem modelling is an important research area.

At the University of Oslo, the Centre for Ecological and Evolutionary Synthesis (CEES) was granted status as a Norwegian Centre of Excellence in 2007 for its work on how living organisms respond and adapt to environmental changes. Climate-change-relevant research at the Centre includes studies of climate effects on bird migration and lake ecosystems. CEES coordinated the Nordic Centre of Excellence “EcoClim” in 2003-2007 with partners from Lund University and the University of Helsinki. EcoClim focused on how climatic variation affects the dynamics of ecological systems, bringing together ecologists,

evolutionary biologists, climatologists, statisticians and mathematicians.

At the University of Copenhagen, the Centre for Macroecology and Evolution seeks to describe and explain temporal and spatial patterns of biological variation. The research at the Centre is focused on how climate as a principal factor affects distribution of life on Earth in the past, today and in the future. Professor Carsten Rahbek at the Centre has received funds from the Danish National Research Foundation to establish a Centre of Excellence starting January 2010.

Another research centre in Denmark focusing on the effects of climatic changes on biological processes and natural ecosystems is the CLIMAITE centre. The Centre involves a consortium of six research groups from Risø DTU, University of Copenhagen, Royal Veterinary and Agricultural University and the National Environmental Research Institute at Aarhus University. CLIMAITE aims to contribute to a more comprehensive understanding of the effects of climatic changes on biological processes and the functioning of natural ecosystems through experiments that manipulate the CO₂ concentration, the temperature and the precipitation to simulate the climate predicted for Denmark in 70 years' time.

Climate Change Impacts on Oceans

As mentioned in earlier sections, the Nordic countries have a long tradition of oceanographic research. Studies of currents, climate and ecosystems in the North Atlantic have been important research themes in former projects, resulting in new knowledge about climate change impact on ocean currents like the Gulf Stream, among other things.

Nordic researchers also make important contributions in the research on marine ecosystem changes. Assessments highlight potential impacts such as changes in the distribution and stock sizes of fish due to higher temperatures and decrease of salinity and more frequent events of algae blooming⁴¹. Another serious climate change impact on oceans is lower pH values, hence acidification, which reduces the capacity of oceans to store CO₂.

Universities and research institutes from Iceland, Norway and Sweden, are Nordic partners in the EU-funded project "European Project on Ocean Acidification" (EPOCA), which was launched in June 2008. The overall goal of the project is to enhance the understanding of the biological, ecological, biogeochemical, and societal implications of ocean acidification.

Finland, Sweden and Denmark border the Baltic Sea, and a large number of former and current projects have assessed environmental changes in this area. The "BALTEX Assessment of Climate Change for the Baltic Sea Basin" (BACC) project published a book in 2008⁴² that assembles, integrates and assesses available knowledge on climate change and related impacts on marine, freshwater, and terrestrial ecosystems in the Baltic Sea basin. The report highlights impacts such as changes in the timing of algae blooms due to less ice cover in the winter and risks of lower salinity due to increased precipitation affecting the runoff. Moreover, higher water temperatures may affect bacterial activity, which can affect nutrient recycling and mineralisation in surface waters. These changes may have a direct influence on the composition and distribution of species in the Baltic Sea.

Arctic Climate Change Impacts

Ecosystems in the Arctic area are in many cases especially vulnerable to climate change, and many Nordic research institutions study impacts of climate change on nature and society in the Arctic region. The "Arctic Climate Impact Assessment" (ACIA) project published its results in 2004. Researchers from Finland, Iceland, Norway and Sweden were in the group of lead authors, concluding among other things that:

- The tree line is expected to move northward and to higher elevations, with forests replacing a significant fraction of the existing tundra.

- Increased forest disturbances due to insect infestations are very likely to result from increasing temperature warming. This could create new opportunities for invasive non-native species to become established.
- Reduced salinity in the North Atlantic Ocean due to melting ice could cause changes in ocean circulation patterns that strongly affect regional climate.
- The southern limit of permafrost is projected to shift northward by several hundred kilometres during this century.
- Climate changes are strongly affecting people in many communities in the Arctic area.
- More flooding, landslides and storms may result in higher costs for infrastructure maintenance.
- Expected decrease in summer precipitation and increased evaporation in some areas, combined with increased temperature, may have negative consequences for both the supply and quality of drinking water.
- Increased water temperatures are likely to lead to a northward shift in the distribution of many species of fish, and to increased growth rates.
- Increased production in agriculture is expected due to longer growing seasons.
- Improved conditions for hydro power production (in the winter time), decreased demand in energy for heating, and increased demand for energy for cooling⁴³ are all expected.

After the publication of the ACIA report, Norway established the Nor-ACIA secretariat at the Norwegian Polar Institute to follow up on the report in Norway. Research groups at Nor-ACIA focus on the impacts of climate change on ecosystems and biodiversity, as well as on impacts on society and people.

More recently, in May 2009, the Greenland Climate Research Centre was opened at the Institute of Natural Resources, University of Greenland. The Centre will focus on climatic changes and the following consequences for nature and societies in the Arctic.

Impacts on Society and Economy

Until recently, most Nordic research within the field of impacts and vulnerabilities was on the natural environment, but today there is also a strong focus on examining the consequences of climate change for societies and economy. Several impact assessments have been made, concluding among other things:

- Low-lying coastal areas in the South of the Nordic region may be affected by sea level rise.
- Increased productivity is expected in forests, but new pests and diseases could emerge and cause damage to trees.
- More precipitation in winter is expected to cause increased runoff with higher risk for floods, along with melting of glaciers in some areas.

The Nordic countries are involved in the EU-funded ERA-Net “Climate Impact Research Coordination for a Larger Europe” (CIRCLE). The purpose of CIRCLE is to promote networking and coordination of national research in the field of climate change. One of the prime objectives of CIRCLE is to organise and execute joint calls of the national research programmes taking part in CIRCLE. The Nordic call of the CIRCLE ERA-Net is funding three projects in 2008-2010:

- “Climate change: A Regional Assessment of Vulnerability and Adaptive capacity for the Nordic countries” (CARAVAN): Coordinated by the Finnish Environment Institute
- “Climate Change adaptation in Norway, Sweden and Finland – Do research, policy and practice meet?”: Coordinated by the Finnish Meteorological Institute
- “Climate change, Community Response and Multilevel Governance”: Coordinated by the Stockholm Environment Institute

Vulnerability at the local level and impacts in economic sectors are also central themes in a number of other projects in the Nordic countries. As in the CARAVAN project, impacts and vulnerability at a local level is the focus

of the Norwegian research project “Community Adaptation and Vulnerability in Norway” (NORADAPT), coordinated by CICERO. Its focus is on how projected changes in climate interact with changes in socioeconomic and institutional conditions and how these interactions shape vulnerability at the local level. The project will develop an indicator-based model for climate change vulnerability assessments.

In Sweden, the Mistra-SWECIA programme includes the module “Impact modelling and applications”, in which researchers explore impacts on for example human health, agricultural and forest production and on ecosystem carbon balance and land use.

Combining a local and sector-based approach, the Finnish project “Map-based Assessment of Vulnerability to Climate Change Employing Regional Indicators” (MAVERIC) aims to map quantitative measures of vulnerability to climate change at municipality scale across Finland. The study will focus on three sectors: agriculture, tourism, and recreation and water resources. MAVERIC is coordinated by the Finnish Environment Institute (SYKE) and involves five other Finnish partner organisations.

As for impact assessments in economic sectors, Finland, Sweden, Norway and Iceland have a solid line of joint research into climate impacts on hydrology and water resources, including impacts on energy supply. The Nordic project “Climate and Energy Systems; Risks, Potential and Adaptation” (CES) is a major multi-party research cooperation addressing issues related to the potential for production and the future security and uncertainties of the Nordic power production systems in the context of climate change. The project is managed the Icelandic Meteorological Office and runs to 2010. It is a continuation of earlier Nordic research initiatives for modelling and impact assessments the energy sector; in 2003-2006 the Nordic-Baltic research project “Climate and Energy” (CE) developed scenarios for the period 2070-2100 for climate and climatic impacts on renewable energy production.

Assessing physical impacts on ecosystems and ecosystem services is essential in order

to develop appropriate responses such as adaptation measures. However, social factors are also important when evaluating the vulnerability of societies to climate change. Many Nordic research groups focus on questions related to the human and social dimensions of climate change. One well-known example is the Department of Sociology and Human Geography at the University of Oslo. Its research focus is on the relations between global climate change and local environmental and social changes. The faculty houses the “Global Environmental Change and Human Security” project (GECHS), which is a part of the International Human Dimensions Programme (see Chapter 6).

At the University of Copenhagen, Professor Kirsten Hastrup, has received a grant from the European Research Council, which will be used to establish a climate centre at the Department of Anthropology. A central activity will be the project “Waterworlds – Natural Environmental Disasters and Social Resilience in Anthropological Perspective”. The ambition of the project is to study local, social responses to environmental disasters related to water, as spurred by the melting of ice in the Arctic and in other glacier areas, the rising of seas that flood islands and coastal communities, and the drying of lands accelerating desertification in large parts of Africa and elsewhere.

FEATURED SCIENTIST: KAREN O'BRIEN

Outside the box

"It was very warm in the summer of '88, and climate change was becoming a big issue in the United States". This is how Karen O'Brien explains her first meeting with climate change and why she decided to write her thesis on the impacts of global warming on Mexico, eventually leading her to an academic career with 20 years worth of experience on social issues related to climate change.

Now a professor in the Department of Sociology and Human Geography at the University of Oslo, O'Brien has worked

extensively on the human dimensions of climate change. "I do research specifically on impacts, vulnerability and adaptation and what climate change means for human security", O'Brien explains. "Environmental changes interact with globalisation processes, and I look at this, as well as how values, worldview and beliefs influence responses to climate change". O'Brien says that climate change is not just an environmental problem that can be viewed separately from development processes, and her work has emphasised the notion of multiple stressors and "double exposure".

One of the challenges we are facing today, according to O'Brien, is how to respond to climate change quickly and effectively. "We have to respond over the next decade, and fortunately we have the knowledge and capacity to do so. It would be irresponsible of us not to

act, when we actually can do something about climate change", she exclaims. "We know who is vulnerable and why, and we know what contributes to greenhouse gas emissions – what we need now is leadership".

CLIMATE CHANGE IS ABOUT THE KIND OF FUTURE WE WANT IN OUR REGION, AND IN THE WORLD, AND IT IS ABOUT OUR OBLIGATION TO DO SOMETHING ABOUT IT.

Karen O'Brien, like many of her colleagues in the Nordic region, also asks for more collaboration between the countries. "In the Nordic countries climate change is sometimes viewed positively among the general public – a four-degrees warming does not sound threat-

ening, when in fact it is catastrophic. The science community must work together to show people what climate change actually will mean, from both a systems perspective and from cultural and human development perspectives". Her viewpoint is that if the Nordic countries collaborate to present a regional understanding of climate change, stakeholders will have a better understanding of how to respond to a changing climate, including what the consequences of not doing so might be.

"We have to take a strong stand on this issue", O'Brien continues. "We think that climate change is about other countries or that we can simply adapt because we are rich. But it is about the kind of future we want in our region, and in the world, and it is about our obligation to do something about it".



5.4. ADAPTATION AND MITIGATION – WHAT ARE APPROPRIATE RESPONSES TO CLIMATE CHANGE?

The knowledge about climate change and its consequences for society and the environment has improved dramatically over recent decades, which has paved the way for an increased focus on how to deal with climate change. Until recently, most research on how to manage the risks related to climate change was focused on ways to reduce greenhouse gas emissions, but, as it has become increasingly clear that further climate change is unavoidable, even with high levels of mitigation, adaptation research becomes more and more important.

Adaptation and mitigation are closely linked; more mitigation implies less adaptation and *vice versa*. The final report from the EU project “Adaptation and Mitigation Strategies: Supporting European Climate Policy” (ADAM) was published in May 2009, concluding, among other things, that a policy scenario combining mitigation and adaptation leads to the lowest costs and residual damages for society⁴⁴. The Stockholm Environment Institute (SEI) was one out of three Nordic partners in the ADAM project. Climate governance, including mitigation and adaptation strategies, is a research area where SEI provides important contributions to policy makers. In the most recent IPCC report, Professor Richard Klein at SEI was coordinating lead author for the chapter about inter-relationships between adaptation and mitigation.

In the following section, we describe Nordic focus areas within the fields of mitigation and adaptation. However, as mentioned previously, the scope of this publication does not cover the large volume of Nordic research on mitigation by environmental technologies within energy, industrial production or waste.

Policy-Relevant Adaptation Research

Several former and current multi-party research projects in the Nordic countries address climate change adaptation, aiming to support the development and implementation of adaptation measures on national and local level, as well as in specific sectors. Developing tools for adaptation is the main focus of the Swedish programme

“Climatools”. The project runs until 2011 and is managed by the Swedish Defence Research Agency (FOI)⁴⁵ on behalf of the Swedish Environmental Protection Agency. Main areas of interest in this project are adaptation related to health, habitation, tourism and outdoor life. Another Swedish project, which has already been mentioned, is the Swedish Mistra-SWECIA programme. The adaptation module in this project focuses on how adaptation is conducted in the society. It deals with stakeholders, institutions and processes and investigates social learning related to climate change adaptation.

The Norwegian project “Community Adaptation and Vulnerability in Norway” (NORADAPT), described under the heading of Impacts and Vulnerabilities, addresses the question of the role of municipal governments in climate change adaptation. CICERO manages NORADAPT and is also managing another adaptation project focusing on municipalities: “Adapting to extreme weather in municipalities”. This project aims to develop a manual for the municipalities to use as a tool in their adaptation work. Research in this project is especially directed at issues concerning drinking water and sewage, cultural heritage and natural resources.

CICERO is also one of several partners in a project led by the University of Oslo called “Potentials of and Limits to Adaptation in Norway” (PLAN). It is a four-year project, ending in 2010, with the goal of investigating how individuals and communities in Norway adapt to climate change. PLAN is based at the Department of Sociology and Human Geography at the University of Oslo and includes geographers, political scientists, urban planners, and anthropologists from several leading Norwegian research institutions. The research focuses on social processes that influence the capacity to adapt, limits to adaptation as a response to climate change and the implications of these limits for human security.

Danish adaptation research projects are described by the Coordination Unit for Climate Change Adaptation Research, led by Aarhus University. One of the projects, running from 2009-2012, focuses on the Danish coastline, aiming to develop new methods for protection

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against flooding and erosion. Protection against floods is also the focus of the Finnish project “Towards Levels of Required Adaptation to Cope with Extreme Weather Events” (TOLERATE). The main objective is to assess what level of adaptation that is needed at a regional level in order to avoid intolerable damage from extreme weather events, such as floods and droughts.

Policy Support for Mitigation

The use of policy tools for climate change mitigation is in focus in several research projects and programmes involving Nordic researchers. The Partnership for European Environmental Research (PEER) recently finished the project “Climate Policy Integration, Coherence and Governance”. It was coordinated by the Finnish Environment Institute, focusing on the effects of climate change policies. Its final report⁴⁶, published in March 2009, emphasises that a successful climate policy requires more integration of climate policy aims in specific policy instruments. The report argues that specific measures to tackle climate change, such as emissions trading, will only be successful if they are coherently integrated with other government policies addressing economic and social issues. The final report is largely based on a number of case studies, two of which were produced in Denmark and Finland.

Research into topics such as climate policy instruments, climate governance and international climate agreements is conducted at several Nordic universities and research institutions by groups within Law, Social Sciences and Economics. Some of them participate in the Swedish-funded “Climate Policy Research Programme” (Clipore), which is a consortium of eight international research organisations that are internationally renowned in the field of climate policy research. Five of the partners are Swedish and one is Norwegian. The program started in 2004 and the current phase ends in 2010. Research focuses on various core issues related to the development and implementation of a future climate regime, such as design of emission trading systems, climate policy and energy markets, climate-friendly technological development, regulation of the

transport sector, climate change and development, adaptation, interplay with trade policy, and legitimacy of climate policy.

Climate change economics is another important area of research that supports governance and decision making. Research in this field is conducted at several Nordic universities and especially worth mentioning is the research at the Institute for International Economic Studies (IIES) at Stockholm University. It is a partner institute in the Mistra-SWECIA programme, where an essential part of the research agenda is to better understand the feedbacks between the human economic system and the natural climate system over long periods of time. Professor Per Krusell, affiliated with the IIES, received an Advanced Investigator Grant from the European Research Council for developing a dynamic quantitative macroeconomic model of the world economy with the climate system as an integral part.

Policy support in the area of mitigation also includes the development of scenarios, illustrating the consequences for various courses of actions. This is a major research area at the DTU Climate Centre at the Risø DTU National Laboratory for Sustainable Energy, where analyses and modelling evaluate the future effect of mitigation efforts in the energy and transport sectors. These subjects are also addressed in the project “Nordic Energy Perspectives” (NEP) which is an interdisciplinary Nordic initiative aiming to demonstrate means for stronger and sustainable growth and development in the Nordic countries. The NEP project analyses the national and international political goals, directives, and policy instruments within the energy area, as well as their influence on the Nordic energy markets, energy systems and the institutional structures. NEP seeks to clarify for decision-makers the consequences of political and strategic decisions for politicians, energy actors and the public. The group of researchers includes scientists from the VTT Technological Research Centre of Finland, Chalmers University of Technology in Gothenburg and the School of Business, Economics and Law at the University of Gothenburg.

Besides changing the way we use and produce energy, avoided deforestation is one of

” BESIDES CHANGING THE WAY WE USE AND PRODUCE ENERGY, AVOIDED DEFORESTATION IS ONE OF THE MOST IMPORTANT MEANS FOR MITIGATING CLIMATE CHANGE.

the most important means for mitigating climate change. In 2007, the Norwegian government launched its International Climate and Forest Initiative, saying it would be prepared to allocate large sums of money to efforts reducing emissions from deforestation and forest degradation (REDD) in developing countries over the next five years. However, to achieve large-scale reductions in greenhouse gas emissions from deforestation, international agreements and institutional structures need to be developed. Several Nordic researchers take part in studies on deforestation; including research on how to include REDD emissions in a future climate regime. The department of Economy and Resource Management at the Norwegian University of Life Science is one example, where Professor Arild Angelsen has made important contributions to research on deforestation. Recently, he edited a book⁴⁷ published by the International Climate and Forest Initiative. Twenty international researchers contributed to the book, discussing design options (such as measurement, scale and funding) for including REDD in the post-2012 global climate agreement.

Issues related to deforestation and land use are also addressed in the project “Land use, land-use change and forestry in relation to global change”. It is led by Linköping University in Sweden, with partners at two other Swedish universities as well as in India and the United Kingdom. The overall focus of the project is to integrate research on land use, land-use change and forestry with the impact of climate variability, sustainable development and carbon sequestration.

As mentioned in earlier sections, several research departments and institutes in the Nordic countries contribute to research in the carbon cycle by analysing emissions from agricultural production. Related to such research, work is also conducted on how to mitigate emissions from agriculture. For example, a research group at the Department of Agroecology and Environment at Aarhus University works on quantifying the amount of greenhouse gases emitted by different forms of agricultural production and identifying the improvement and development possibilities that improved production systems would present.

FEATURED SCIENTIST: PER KRUSELL

Modelling the big scheme

Per Krusell has been living in the United States for the past 22 years where he, amongst other positions, has been employed as Professor of Economics at the University of Princeton. His academic career is long and impressive, but has, for the most part, had little to do with climate change research.

That changed, however, when he realized that his expertise in macro-economic modelling could be extremely valuable for climate change research.

“It was a bit of luck, really”, Krusell explains. “I happen to be a specialist on macro-economic modelling and a big global climate-macro model is needed. Thus, it was a great opportunity for me to use my abilities in a very productive way, and I must admit it feels good to contribute with something there is such an explicit need for”.

The model to which Krusell refers is one he is working on under the auspices of Mistra-SWECIA. IPCC does not have a model that explains how the economic part of the world functions, something Krusell’s model will attempt to do. The model will explain the interconnectivity between economics and climate, i.e., how the economy affects the climate and vice versa, thus being an important tool for policy makers and in the climate

change debate. The model is scheduled to be ready in a couple of years, and, in the mean time, Krusell is simultaneously working on models for more general policies, such as optimal energy taxes and to what extent energy savings have been useful.

“NOT ONLY IS THERE INCREASED INTEREST AMONG ECONOMISTS, BUT YOU CAN ALSO SEE IT ON THE FUNDING SIDE.”

Classic macroeconomists are generally not known to combine economics and climate, but Krusell says he has observed a change among his colleagues over the years. “Not only is there increased interest among economists, but you can also see it on the funding side,” Krusell says. “I was given a substantial grant from the economics section

of the European Research Council to work on a project about climate change”.

Although Krusell has spent much of his time abroad, he has not cut his ties to Sweden completely and is now coming back permanently. He will be at IIES at the University of Stockholm, and his activities there have led to the prestigious ERC grant. “There is a lot of interest in my work in Sweden, and I believe it is possible to have an impact there, both in terms of contributing with policy advice but also in terms of educating. It is all very exciting”.





6. Nordic Participation in International Research Cooperation within Climate Change

International research cooperation is highly relevant for scientific questions that transcend geographical boundaries, and climate change is an area where international cooperation is widespread and necessary. Studies indicate that the Nordic countries increased their research cooperation during the last decade, as the international cooperation in published articles has increased.⁴⁸ As for international research cooperation within climate change, a recently published bibliometric study⁴⁹ illustrates the international cooperation of Danish climate change researchers. While the United States is the most frequent partner country, the other Nordic countries are also important partners for Danish climate change researchers.

The task of advancing the understanding of the processes that determine the Earth's climate is inherently global in nature, and international cooperation is essential for dealing with climate change. As illustrated by examples in previous chapters, Nordic researchers take an active part in European research cooperation, as well as on a Nordic level. In addition, universities and research institutes have bilateral cooperation with partners in other countries. In this section, however, we focus on some of the many organisations on the global and regional scale that provide platforms for international cooperation within climate change and give examples of their projects and activities. Our main focus is activities with Nordic participation.

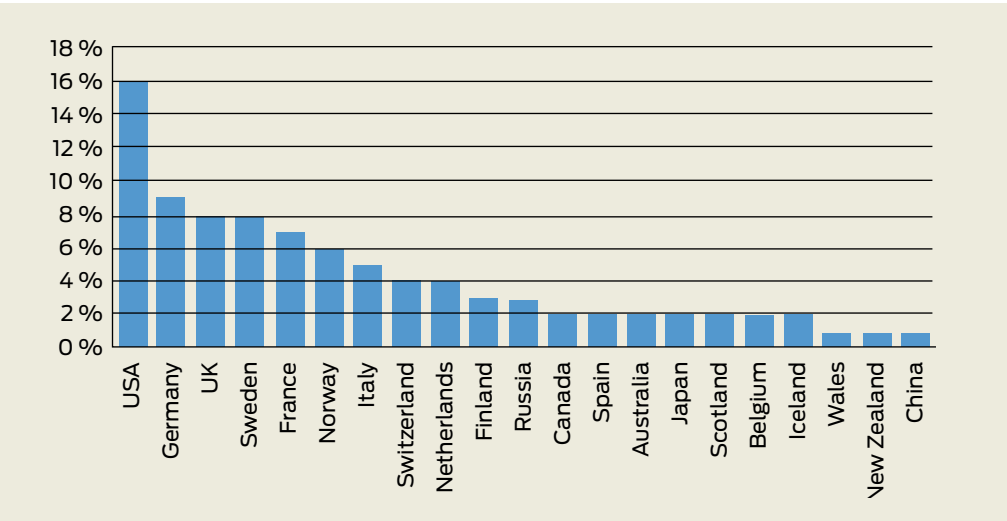


FIGURE 5: Joint publications between Danish and foreign climate change researchers 2003-2007⁵⁰. The figure shows the most frequent partner countries of Danish researchers' climate change research publications, as mapped in a Danish bibliometric study.

Global Scale International Research Programmes Related to Climate Change

The Earth System Science Partnership (ESSP) is a partnership of four international, global-change research programmes, aiming to promote interdisciplinary and cross-programme research:

- The World Climate Research Programme (WCRP)
- International Geosphere-Biosphere Programme (IGBP)
- International Human Dimensions Programme on global environmental change (IHDP)
- International Programme on Biodiversity (DIVERTAS)

The World Climate Research Programme was the first major international global-change research programme. It was established under the sponsorship of the World Meteorological Organisation (WMO) and International Council for Science (ICSU) in 1980. The Intergovernmental Oceanographic Commission (IOC) became a co-sponsor in 1993. Nordic researchers contribute to a wide range of international research activities under the World Climate Research Programme, such as “Climate Variability and Predictability” (CLIVAR), “Climate and Cryosphere” (CliC) and “Global Energy and Water Cycle Experiment” (GEWEX). CliC has its main office at the Polar Environmental Centre in Tromsø, Norway, and is supported by the Norwegian Polar Institute and the Norwegian Research Council. GEWEX is implementing a series of regional studies. One such initiative is the “Baltic Sea Experiment” (BALTEX), involving many Nordic research institutions.

The International Geosphere-Biosphere Programme (IGBP) studies the interactions between biological, chemical and physical processes and how they influence (and are influenced by) human systems. Its secretariat is part of the Royal Swedish Academy of Sciences in Stockholm, Sweden. A Nordic contribution to IGBP’s research activities is the “Global Land Project” (GLP). It has its international project office at the Department

” INTERNATIONAL COOPERATION IS ESSENTIAL FOR DEALING WITH CLIMATE CHANGE.

of Geography and Geology at the University of Copenhagen, Denmark, where Professor Anette Reenberg chairs the GLP Scientific Steering Committee. Another IGBP activity with Nordic involvement is the Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) that has its international project office located at the University of Helsinki, Department of Physics Division of Atmospheric Sciences and Geophysics.

The International Human Dimensions Programme on global environmental change (IHDP) is another important arena for international cooperation for several Nordic researchers focusing on global change. “Global Environmental Change and Human Security” (GECHS), chaired by Professor Karen O’Brien at the Institute for Sociology and Human Geography at the University of Oslo, is one of IHDPs six core science projects.

The International Programme on Biodiversity (DIVERTAS) aims to promote an integrated biodiversity science, linking biological, ecological and social disciplines, as well as providing the scientific basis for the conservation and sustainable use of biodiversity. Professor Thomas Elmqvist, Department of Systems Ecology at Stockholm University, contributes through his work as co-chair of the scientific committee for the core project BioSustainability.

The four major research programmes within the ESSP framework also initiate joint projects. One example is the “Global Carbon Project” (GCP), which aims to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions together with the interactions and feedbacks between them. Nordic scientists have been involved in a number of the regional contributions from Europe to the GCP-project, such as CarboEurope, CARBOOCEAN and CARBO-North.

International Research Cooperation on Observations and Modelling

Infrastructures for observing climate and environmental change are owned and operated by the large number of different stakeholders across the globe, with the information being coordinated by a number of international

and regional networks. The Nordic meteorological institutes contribute with observation data from their respective territories to the global observation systems for climate (GCOS), oceans (GOOS) and terrains (GTOS), and they are involved in a number of networks for coordinating and improving observation capacities both within *in situ* and remote sensing.

The global observing system for climate (GCOS) provides critical input to climate models, which is a research area in rapid development. As described in earlier sections, Nordic climate modelling groups are involved in a number of international consortia for climate modelling. The “Coordinated Regional Downscaling Experiment” (**CORDEX**) is initiated by the World Climate Research Programme. It aims to improve coordination of international efforts in regional climate downscaling. The Swedish and Danish meteorological institutions are involved in CORDEX, and they are also partners in the “EC-Earth” consortium for the development of a new Earth System Model. Earth System Modelling (ESM) is also conducted within the COSMOS ESM network, led by the Max Planck Institute for Meteorology in Germany, with Finnish participation.

International Cooperation on Arctic and Antarctic Climate Change Research

The Arctic is experiencing some of the most rapid climate changes in the world. Due to several mechanisms and feedback processes, warming of the Arctic can amplify global warming⁵¹. Thus, it is essential that decision-makers have the latest and best data and information available regarding ongoing and projected changes in the Arctic. International cooperation within Arctic research is extensive and the joint research efforts follow a long tradition encouraged by organisations such as the International Arctic Sciences Committee (IASC), the Arctic Ocean Sciences Board (AOSB), the Working Groups of the Arctic Council, the World Climate Research Programme, the International Arctic Social Sciences Association (IASSA), and many others. Nordic countries are members of these organisations and take an active part in their

work. The programme office for IASC, for example, is located at the Royal Swedish Academy of Science, and the Norwegian Institute of Marine Research chairs the AOSB. Although Nordic interests are mainly in the Arctic region, Nordic countries are also involved in international research cooperation in the Antarctic area with Finland, Norway and Sweden being members of the Scientific Committee on Antarctic Research (SCAR).

The Nordic countries were involved in many projects in the International Polar Year (IPY) 2007-2008, which was sponsored by the International Council for Science and the World Meteorological Organisation. The main Nordic participation in IPY was in projects in the Arctic region, but Nordic researchers were also involved in Antarctic research, aiming, among other goals, to improve understanding of the role of the Antarctic for global climate.

European Research Cooperation

As illustrated by several examples in the previous chapter, the EU is an important funding source for Nordic research on climate change and its funding promotes research cooperation across borders. According to an evaluation⁵² of the first two years of the EU 7th Framework Programme for Research and Technological Development (FP7), almost 3000 Nordic applicants are represented in the projects that received funding. The FP7 funds a long list of climate-change-related research projects, with strong representation of Nordic researchers considering the small size of the countries.

The ERA-Net Scheme was introduced in EU 6th Framework Programme (FP6) for research and development. It was established by the EU Commission to increase collaboration and coordination of national and regional research. Under the ERA-Net Scheme, research councils and other national research funding agencies in Europe can apply for funds to collaborate in developing “best practice” in the administration of research grant applications, and to call jointly for proposals. As mentioned in previous sections, the “Climate Impact Research Coordination for a Larger Europe” (CIRCLE) is one such initiative. Another exam-

ple is the “European Consortium for Ocean Research Drilling” (ECORD), which started as an ERA-Net initiative and has continued as a European partner in the “International Ocean Drilling Program” (IODP).

Another arena for European research cooperation will be provided by the European Institute of Innovation and Technology (EIT) through the creation of “Knowledge and Innovation Communities” (KICs). The first two to three KICs will be chosen in the beginning of 2010 among three priority areas, one of which is climate change mitigation and adaptation. According to EIT, the selection will be based on competitive, transparent and excellence-driven criteria for periods of seven to fifteen years, to ensure mid- to long-term sustainability of the chosen partnerships.

Baltic Cooperation on Climate Change

The countries bordering the Baltic Sea⁵³ cooperate on several areas within research related to climate change. The Baltic Sea is a large, brackish water basin, and, due to its semi-enclosed position and restricted water exchange, it is particularly vulnerable to climate changes which affect dynamics of water temperature, salinity, and hence the inhabiting flora and fauna.

Nordic research cooperation related to climate change and the Baltic Sea includes the Baltic Nest Institute (BNI). It is a research institution located at the Stockholm Resilience Centre in Sweden and at the National Environmental Research Institute (NERI) in Denmark. The institute uses information from a range of institutions around the Baltic Sea for integrated, large scale modelling describing ecosystem dynamics and for supporting systems for marine management.

BNI is involved in several projects supported by the “Baltic Organisations Network for Funding Science” (BONUS) ERA-Net. BONUS was established in 2003 as part of the FP6, aiming to develop and broaden the Baltic Sea research funding cooperation. The ERA-Net project is finalised but the partners continue their work, implementing a Joint Baltic Sea Research Programme (BONUS-169).

THE EU IS AN
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Climate-change-relevant research will also be conducted within the framework of the EU Strategy for the Baltic Sea. The European Commission published a communication concerning the European Union Strategy for the Baltic Sea Region in June 2009⁵⁴ and one of the first transnational projects contributing to this strategy is the project “Climate Change: Impacts, Costs and Adaptation in the Baltic Sea Region” (BaltCICA). BaltCICA is led by the Geological Survey of Finland and involves research partners from Denmark, Finland, Norway and Sweden, among others.

As already mentioned, another major collaborative research initiative in the region is the “Baltic Sea Experiment” (BALTEX). It was launched in 1992 as a part of the Global Energy and Water Cycle Experiment (GEWEX) within the World Climate Research Program. The second phase of BALTEX started in 2003 and will last until 2013. The overall goal is to integrate efforts to gain a better understanding of the water, energy and matter cycles in the Baltic Sea basin in the light of climate change, and to foster the development of coupled models contributing to a regional Earth System Modelling of the Baltic Sea basin.

FEATURED SCIENTIST: EYSTEIN JANSEN

Interdisciplinary research teams and long-term funding key to success

Eystein Jansen is the Director of the Bjerknes Centre for Climate Research in Bergen, Norway. He is also a member of the Norwegian Academy of Sciences, the Norwegian Academy of Technological Sciences and the Norwegian Academy of Polar Sciences, to mention only a few of his accomplishments.

Since the 1980s, Jansen has been studying marine geology and has, over time, focused his research on natural climate change versus anthropogenic climate change and the impact of changes in the Gulf Stream system on the climate in Europe and the High North. His efforts led him to the post of coordinating lead author for the chapter on paleoclimatology in the IPCC's fourth assessment report, a report that obtained further attention after the announcement of IPCC as the joint recipient of the 2007 Nobel Peace Prize.

"The Nobel Peace Prize was a great inspiration and an acknowledgement of the work we do, and it did a lot in terms of public awareness", Jansen says. "However, it did not give rise to additional funding", he continues, and

he points to what he believes is one of the bigger obstacles for Nordic climate change research today: "Climate change research demands long-term, predictable financing, something there is too little of in the Nordic region at present. There is too little long-

term national financing and not enough co-ordination between the Nordic countries". Jansen believes that to provide the best possible research on climate change issues, there is a need for interdisciplinary research teams, combining expertise on past climate changes with expert focus on future climate changes.

THE GULF STREAM
IS KEY TO CLIMATE
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HIGH NORTH.

Jansen himself aims to provide better predictions of future regional climate scenarios. "The Gulf Stream is key to climate changes in Europe and the High North and extremely sensitive such that it experiences rapid changes. It is impossible to produce reliable predictions about future climate scenarios in these areas without understanding the variability and nature of the Gulf Stream system", Jansen affirms.





7. Climate Change Research Relevant for Developing Countries

The Nordic countries have a long tradition for committing to sustainable development and environmental conservation in the developing world. Sweden, Norway and Denmark rank among the top five in OECD's statistics over official development aid per unit gross national income (GNI)⁵⁵. A long line of reports have concluded that developing countries are particularly vulnerable to climate change and that expected climate changes could threaten the UN's Millennium Development Goals ambition of fighting poverty. Hence, the link between reduction of poverty, development and climate change policy is becoming more and more important. As a result, organisations for development aid around the world are increasingly integrating climate change concerns into their programmes.

In this context, climate change research plays an important role. To promote sustainable development from a climate change perspective, decision-makers in the South as well as supporting partners in the North, need information about expected climate changes on a regional scale, impact and vulnerability in different regions and sectors and barriers for adaptations. Other areas of research relevant to developing countries include research into international climate policy agreements, research into funding mechanisms for adaptation and mitigation in poor countries, as well as studies of new sources of financing.

In the Nordic countries, there is solid political support for the idea of using Nordic know-how about climate change mitigation and adaptation to the benefit of developing countries. Although the contribution may not be very large in volume, several Nordic universities and research institutes make important contributions to research in areas of relevance to developing countries. Numerous research centres and institutions focus a major part of their research on themes relevant for developing countries. Themes include biodiversity, livestock production, soil conservation, forest ecosystems, water management and food crops, as well as studies on adaptation and vulnerability. Three Danish research networks⁵⁶ published an overview in 2008 of Danish research competences and research projects with regards to climate change impacts, mitigation and adaptation in developing countries, identifying 64 ongoing or recently finished projects⁵⁷. In the following sections, a selection of climate change research projects with special relevance to developing countries involving Nordic researchers is presented.

The Swedish-funded "Climate International Policy Research Programme" (Clipore) described in Chapter 5 addresses several issues specific for developing countries. The focus is on themes such as the interplay between climate and development, adaptation (funding, implementation and

priorities), policy instruments and bio resources and livelihood. This work is led by the Stockholm Environment Institute (SEI), which is involved in a long line of projects related to developing countries. For instance, SEI is a collaborating institution in a project led by the University Centre for Development and the Environment (SUM) at the University of Oslo and the Institute for Innovation and Economic Organisation at the Norwegian School of Management. The project is called “Sustainability for the 21st Century: Overcoming Limitations to Creative Adaptation to Climate Challenge” (CERES21). The objectives of the project comprise identification of cultural, political and economical sources of the main problems hindering creative adaptation to the climate challenge in Norway, China and Ghana.

The University of Oslo recently launched a new interfaculty research area called “Environmental change and sustainable energy” (MILEN). It covers a wide range of topics related to sustainable energy, but also addresses environmental issues not directly related to energy production and consumption, such as climate change and North-South issues. MILEN is part of the research cooperation between the University of Oslo and the University of Dar Es Salaam.

Air Pollution, Monsoons and Climate Change

The Nordic meteorological institutes have important expertise that have been used in several projects in developing countries, such as regional climate modelling and capacity building for meteorology and climate research. They are also involved in research related to air pollution and its effects on regional climate change, which is highly relevant for several regions in the developing world. One example is the EU-funded project MEGAPOLI⁵⁸, mentioned in Chapter 5, led by the Danish Meteorological Institute. MEGAPOLI focuses on the relation between air pollution and regional climate change in megacities.

Issues related to climate change and pollution is also a core theme at the international “Atmospheric Brown Clouds” project

(ABC). The meteorological institution at Stockholm University (MISU) is one of the participants that works towards establishing a network of ground-based monitoring stations throughout the Indo-Asian and the Pacific regions to study the composition and seasonal patterns of so-called brown clouds and their impact on regional climate. Results indicate impacts such as the slowing down of the monsoon circulation and reduction in monsoon rainfall⁵⁹, with consequences for agriculture and water budgets.

Climate Change and Water

Changes in monsoon patterns have the potential to affect many poor countries, and the subject is also investigated in the “African Monsoon Multidisciplinary Analysis” project (AMMA). AMMA is an international project with participation from the University of Copenhagen, aiming to improve fundamental understanding of the variability of the West African monsoon and its societal impacts, as well as to improve the monitoring and prediction of the West African environment. Research includes studies in aerosols and chemistry, the water cycle, atmospheric feedbacks and climate modelling.

Possible changes in monsoon variability is just one of many examples of the major challenges related to changes in water cycles caused by climate change. Changes in precipitation patterns increase the risks for floods in some areas, whereas other areas will be more affected by drought. Melting of ice in polar areas and in glaciers elsewhere causes sea level rise and risks for floods, as well as reduced access to fresh water in some areas. Exposed areas include large parts of the Asian region, where several hundreds of thousands of people are dependent on water resources from the Himalaya. This is addressed in a research programme led by the Institute of Earth Sciences at the University of Iceland and the Icelandic Meteorological Office, who use Icelandic competence in glaciology to study glacial changes in the Himalaya and the consequences for economic and social development.

Because water is such an important resource, shortage of water could increase

the risk of conflicts when various interests compete over limited supply. This is the theme for the project “Conflict and cooperation in local water governance”, which is coordinated by the Danish Institute for International Studies. Together with national and international partners, it explores local water conflicts and cooperation in Bolivia, Mali, Nicaragua, Vietnam and Zambia. Social dimensions of challenges related to water are also addressed in the “Waterworld” project, described in Chapter 5. Waterworld aims to improve the understanding of human and social impacts for communities hit by natural disasters related to water, such as increased sea level or droughts.

Land Use and Forests

Lack of water has serious implications for human life, not least for food security and conditions for agriculture. Several research groups in the Nordic countries conduct agricultural research relevant to developing countries. In the Danish overview⁶⁰ referred to above, one-third of the projects mapped focused on climate change and agriculture. Research topics include impact assessments, irrigation methods, research on crop species and land restoration. For example, the “Land Restoration Training programme” (LRT), at the Agricultural University of Iceland is a new programme on restoration of degraded land and sustainable land management, aiming at assisting developing countries in capacity development within this field.

A large international project with agriculture ecosystems as one of the key topics, is the “Land use and sustainable development in Developing Countries” (LUPIS). LUPIS is a major research project financed by the EU, involving a coalition of researchers from 15 different countries in Africa, Latin America, Asia and Europe. Nordic participation is represented by the Centre for Development and the Environment at the University of Oslo, which is responsible for research related to biodiversity and natural resource management.

Forest research, biodiversity, natural resource management and avoided deforestation are all important topics addressed

by Nordic researchers in the research network “Forest, Climate and Livelihood” (FOCALI). The network focuses on forest and poverty alleviation and is led by the Centre for Climate Science and Policy Research at Linköping University in Sweden. Researchers from this centre will, in cooperation with researchers from Gothenburg University, Chalmers University of Technology and the Swedish University of Agricultural Sciences, develop new knowledge and methodology in order to facilitate and improve climate and poverty-oriented forestry efforts.

Land use and forests are also central in the EU-funded project “Quantification, Understanding and Prediction of Carbon Cycle and Other GHG Gases in Sub-Saharan Africa” (CarboAfrica). Lund University in Sweden is one out of 15 international partners in the consortium aiming, among other things, to set up a first attempt of a greenhouse gas fluxes monitoring network of Africa.

Policy Instruments and International Agreements

The FOCALI project mentioned above will also focus on global instruments for carbon storage in forest ecosystems. Global instruments will be necessary to harvest the full potential for mitigation by avoiding deforestation, and it is a major issue when it comes to financing other mitigation measures and adaptation in the developing countries. Several activities involving Nordic researchers aim to identify mechanisms and approaches by which the climate regime can better integrate the concerns of developing countries. As for instruments for supporting mitigation efforts, several research groups in the Nordic countries address the question of how the Clean Development Mechanism (CDM) can be further developed. One of these is the UNEP Risø Centre on Energy, Climate and Sustainable Development, which is involved in several projects assessing carbon finance mechanisms.



8. Climate Change Research in the Years to Come

Significant progress in understanding and projecting climate change has been made over the last decade and scientific information is continuing to accumulate at a rapid pace. At the same time, governments, the public and other stakeholders are increasingly concerned about climate change, and policy makers are highly dependent on reliable information in order to be able to manage the climate change risks.

Although scientific progress has been great, uncertainties remain. Gaps of knowledge need to be filled in by many research fields to reduce uncertainty related to climate change. The Chairman of the IPCC outlined some of these in a “vision paper” at a scoping meeting in July 2009 for IPCCs next assessment report (AR5):⁶¹

- Carbon cycle, feedbacks, and interactions with other cycles
- Ocean ecosystems and in particular ocean acidification in all its dimensions
- Clouds, aerosols, black carbon and atmospheric chemistry
- Sea level rise and its regional expression, dynamics of large ice sheets and potential instabilities
- Evolution and trends related to a range of new technologies
- Costs of different stabilization levels and corresponding costs of adaptation

- Infrastructure investments when adaptation and mitigation policies are taken into account
- Evolution and trends in greenhouse gas emissions
- Specific regional information on various aspects of climate change
- Instabilities and irreversibility of climate change, “tipping points”

Over recent decades, climate change research has focused for the most part on the climate system, impacts in general terms, and on mitigation⁶². However, as the focus on the risks of climate change increases, climate change research has more and more spread into the areas of social and humanistic sciences. It is increasingly clear that climate changes are continuing and that not even the most optimistic scenario would prevent further changes in climate, which is why interest increases in research related to vulnerabilities, impacts and adaptation.

The Partnership for European Environmental Research (PEER) illustrates the development in a stylised diagram (Figure 6).

Increased Cooperation – and Specialisation

Due to the urgent drive to develop plans to reduce potential impacts and vulnerability and to enhance adaptive capacity, the co-operation between scientists and policy makers has accelerated, causing a gradual

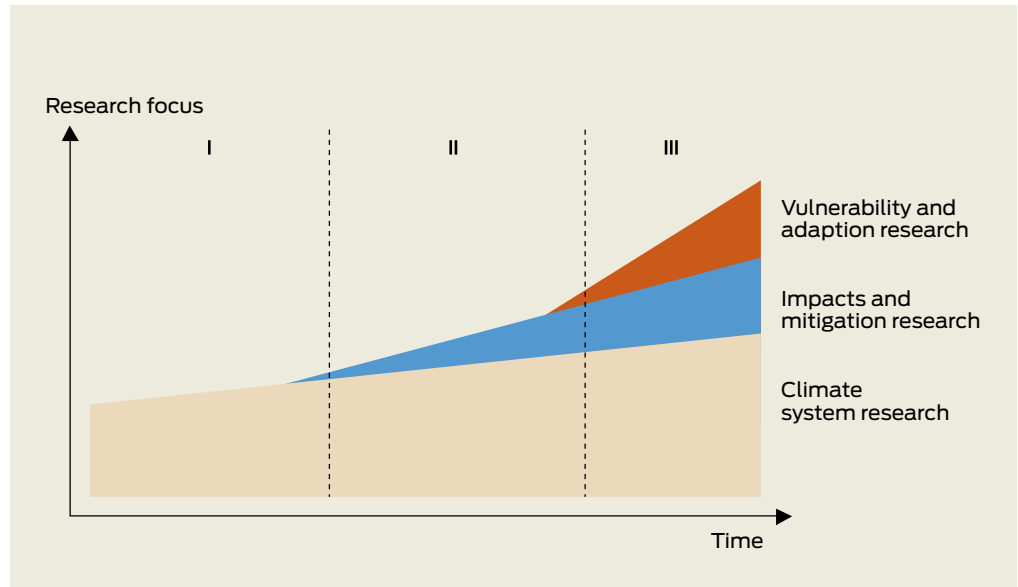


FIGURE 6: Increase in climate change research over time, from approximately 1980 onwards⁶³. This is a stylised diagram, and not a quantification of the balance between the different types of research or overall level of spending on climate change research.

shift from pure science towards a combination of pure and applied science⁶⁴. Moreover, to meet the needs of decision-makers, climate change research is increasingly conducted in cooperation among disciplines, organised around specific societal challenges. Such cross-disciplinary research, with an end-to-end approach (from basic science to decision support) is needed to find answers on how to solve important problems caused by climate change, for example fresh water access and food security.

Due to the complexity of both societies and the climate challenge, the trend towards more cooperation between disciplines and between the scientific community and policy makers is likely to continue. At the same time, however, it is clear that the quality of the cross-disciplinary initiatives is dependent on high-quality basic research. Hence, the traditional research approach based on scientific disciplines, which has led to significant advances in our understanding of the climate system, still has a key role to play.

In addition to these general trends, the IPCC's next assessment report and a number of other recent and new activities related to climate change may give a hint of where focus will be strong in the years to come.

COP15 and the IPCC Assessment Report

The negotiations of a new international response to climate change, to be agreed upon at the United Nations Climate Change Conference (COP15) in Copenhagen in December 2009, have stimulated a great deal of interest in research on institutional mechanisms and climate change governance. The outcome of COP15 will most likely trigger a continued interest for these topics, as further research will be needed in order to develop a working architecture of a future international climate change regime.

Political trends on the national and regional levels are also drivers behind the strong interest for research in climate change governance and policy instruments. Climate-specific measures as well as the integration of climate change aspects in general policies have substantially increased over the last years, and better understanding of the economic and social processes involved when implementing these policies may be crucial for their success.

Closely related to issues concerning the political decision making and institutional mechanisms, is the topic of economics of climate change. The IPCC has identified this as an area of priority for the next assessment report. At the scoping meeting in July 2009,

” GAPS OF KNOWLEDGE NEED TO BE FILLED IN BY MANY RESEARCH FIELDS TO REDUCE UNCERTAINTY RELATED TO CLIMATE CHANGE.

the Chairman’s vision paper, described the input submitted to the IPCC from governments, organisations and lead authors of earlier assessment reports. This paper highlighted a scientific debate on the economics of climate change that is growing ever more complex, and which now includes a wide range of issues such as decision making under uncertainty, inter- and intra-generational justice, the costs of mitigation when the availability of technologies is limited or participation in international agreements is delayed, and the economics of adaptation.⁶⁵

Climate projections have been a cornerstone of all previous IPCC assessment reports, and this will continue to be the case in the next report. This contributes to spur interest for climate modelling and efforts within the climate modelling community to contribute to the IPCC scenarios have already started, also among Nordic climate scientists, as described previously in this publication.

The Legacy from the International Polar Year

The International Polar Year (IPY) 2007-2008 has been acclaimed as the largest international research collaboration to date. The formal observational period ended in March 2009, but many IPY projects and their off-spring continue, contributing to keeping polar research on the agenda. The IPY contributed to improved understanding of the role of the polar regions in the Earth system. Polar changes are critical, because various feedback effects have the potential to accelerate the rates of global changes. In the report “State of Polar Research”, the World Meteorological Organisation and the International Council for Science argue that need for Polar research has never been greater⁶⁶. The legacy from the IPY will most likely keep the focus on Polar research strong in the years to come, even after the finalisation of the IPY projects – not least so in the Nordic countries where there are long standing traditions of arctic research.

The Impact of European Funding

Nordic researchers benefit from European research cooperation, both as a source of financing and as an arena for international collaboration. Therefore, the thematic focus in the Framework Programme for Research and Development will be a factor determining the priorities of Nordic research institutes and universities. In 2009, the overarching priority of the environment theme was “Adaptation to climate and environmental change and related issues such as sustainable cities and coastal zones”. The call for 2010, published in July 2009, addresses “Environmental safety and welfare” as an overarching theme for activities across the work programme for environmental and climate change research⁶⁷. The objective is to contribute to assessing, reducing and preventing tensions and conflicts related to the depletion of natural resources and environmental services that are rising due to rapid environmental changes and/or natural and man-made hazards. The calls for 2010 also include a special focus on Africa and the theme “Oceans of tomorrow”, both of which include climate relevant research topics.

Nordic Climate Change Research in the Years to Come

As illustrated earlier, Nordic researchers are attractive partners in several areas of climate related research, such as paleoclimatology, climate modelling, atmospheric research, oceanography and polar research, as well as impacts and adaptation research. As the Nordic countries are small in size, international co-operation is important for Nordic research institutions, both in terms of knowledge transfer and scope, but also because it represents an additional source of funding. The EU Framework Programmes have been especially valuable in this sense.

Many of the researchers who have given input to this policy brief highlight that insufficient funding at the national and Nordic level is an important barrier for releasing the full potential within Nordic climate change research and increased Nordic cooperation in this area. Nordic initiatives have played an important role to facilitate co-

operation between Nordic research institutes, but to establish more joint Nordic research projects increased funding and more long-term frameworks are needed.

However, as described in Chapter 4, it appears that funding for climate change research in the Nordic countries will increase in the years to come, and important activities in this area have been initiated at the Nordic level. Increased funding will enable Nordic climate change researchers to step up their efforts for contributing to reducing uncertainties related to climate change, as well as to develop appropriate responses to climate change.

Although some countries are still in the process of specifying future priorities within climate change research, priorities at the national and Nordic levels indicate certain areas that will be important in the years to come, including climate modelling, impacts on natural resources and primary industries, as well as adaptation studies.



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Global Carbon Project (2008) "Carbon budget and trends 2007"

Government of Iceland (2007) "Iceland's Climate Change Strategy"

Integrated Carbon Observing System (2008) "Integrated Carbon Observing System - national profiles, stakeholder meeting"

Intergovernmental Panel on Climate Change (2007) "Climate Change 2007: Synthesis Report"

International Council for Science/World Meteorological Organisation Joint Committee for the International Polar Year 2007–2008 (2009) "The State of Polar Research"

IPCC (2007) Climate Change 2007: Synthesis Report

IPCC (2009) "Chairman's vision, AR5 Scoping Meeting; Venice, Italy, 13-17 July 2009"

IUFRO (2009) "Adaptation of Forests and People to Climate Change – A Global Assessment"

Koordineringsenhet for forskning i klimatilpasning (2009) "Klimatilpasning – 5 centrale forskningstemaer"

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Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy (2009) "Mapping of climate research in Denmark"

Mistra Swecia "Mistra Swecia - Climate, Impacts & Adaptation" (information folder)

Nordic Council of Ministers (2008) "Förslag till programme för nordisk toppforskning inom energi, miljö och klimat"

Nordic Council of Ministers and Nordic Council, "Co-operation for Strength," (2005)

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Rummukainen, Markku and Källén, Erland (2009) "Ny klimatvetenskap 2006-2009"

Seppälä, Buck and Katila (ed.) (2009) "Adaptation of Forests and People to Climate Change. A Global Assessment Report"

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The European Commission (2009) "FP7 Subscription, Performance, Implementation during the first two years of operation 2007-2008"

The Finnish Ministry of the Environment (2005) "Finland's fourth national communication on Climate Change - Under the United Nations Framework Convention on Climate Change"

The Global Carbon Budget Project (2008) "CarbonBudget 2007" (presentation)

The Icelandic Ministry of the Environment (2005) "Iceland's fourth national communication on Climate Change - Under the United Nations Framework Convention on Climate Change"

The Norwegian Ministry of the Environment (2005) "Norway's fourth national communication on Climate Change - Under the United Nations Framework Convention on Climate Change"

The Research Council of Norway (2006) "Nasjonal handlingsplan for klimaforskning"

The Research Council of Norway (Oct 2008) "Klimaforliket: Opptrappingsplan for klimaforskning - første innspill fra Forskningsrådet ad volum og innretning"

The Swedish Ministry of the Environment (2005) "Sweden's fourth national communication on Climate Change - Under the United Nations Framework Convention on Climate Change"

Tyndall Centre for Climate Change Research (2009) "Adaptation and Mitigation Strategies: Supporting European Climate Policy - The Final Report from the ADAM Project"

Umhverfisstjórnuneytið (2008) "Hnattrænar loftslagsbreytingar og áhrif þeirra á Íslandi – Skýrsla vísindanefndar um loftslagsbreytingar"

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United Nations World Commission on Environment and Development (1987) "Report of the World Commission on Environment and Development: Our Common Future"

University Centre on Svalbard (2009) "Annual Report 2008"

University of Copenhagen (2009) "Climate Change: Global Risks, Challenges & Decisions - Synthesis Report"

University of Oslo (Aug 2008) "Environmental changes and sustainable energy as a multidisciplinary research area - supplementary strategic document"

U.S. Climate Change Science Programme (2008) "Climate Models: An Assessment of Strengths and Limitations"

US Climate Change Science Program (2002) "Draft White Paper: International Cooperation In Climate Change Science"

World Meteorological Organisation (2009) "WMO statement of the status of the global climate in 2008"

World Meteorological Organisation (2009) "The State of Polar Research"

World Resource Institute (2005) "Navigating the Numbers Greenhouse Gas Data and International Climate Policy"

APPENDIX A

NORDIC RESEARCH ORGANISATIONS CONDUCTING CLIMATE CHANGE RELATED RESEARCH

DENMARK

Aalborg University	http://www.aau.dk
Aarhus University	http://www.au.dk
Danish Forest and Landscape Research Institute	http://www.sl.life.ku.dk
Denmark's Meteorological Institute	http://www.dmi.dk
Danish Technical University	http://www.dtu.dk
Geological Survey of Denmark and Greenland	http://www.geus.dk
National Environmental Research Institute	http://www.dmu.dk
Risø DTU	http://www.risoe.dk
The Danish Institute of Agricultural Sciences	http://www.agrsci.org
UNEP Risoe Center	http://uneprisoe.org
University of Copenhagen	http://www.ku.dk
University of Roskilde	http://www.ruc.dk
University of Southern Denmark in Odense	http://www1.sdu.dk/E/Odense.html
The Faroe Marine Institute	www.hav.fo

FINLAND

Finnish Environment Institute	http://www.environment.fi
Finnish Forest Research Institute	http://www.metla.fi
Finnish Institute of Marine Research	http://www.fimr.fi
Finnish Meteorological Institute	http://www.fmi.fi
Geological Survey of Finland	http://www.gtk.fi
MTT Agrifood Research	http://www.fmi.fi
Technical Research Centre of Finland	http://www.vtt.fi
Turku School of Economics	http://www.tse.fi
University of Joensuu	http://www.joensuu.fi
University of Jyväskylä	http://www.jyu.fi
University of Kuopio	http://www.uku.fi
University of Lapland	http://www.ulapland.fi
University of Oulu	http://www.oulu.fi
University of Turku	http://www.utu.fi
University of Helsinki	http://www.helsinki.fi/university

ICELAND

Iceland Marine Research Institute	http://www.hafro.is
Icelandic Meteorological Office	http://en.vedur.is
Institute for Meteorological Research	http://www.riv.is/
The agricultural University of Iceland	http://www.lbhi.is/
University of Iceland	http://www2.hi.is
University of Akureyri	http://www.unak.is

NORWAY

Bjerknes Centre for Climate Research	http://www.bjerknes.uib.no
Bioforsk	http://www.bioforsk.no
CICERO	http://www.cicero.uio.no
Fridtjof Nansen Institute	http://www.fni.no
Nansen Environmental and Remote Sensing Centre	http://www.nersc.no
Norwegian Institute of Air Research	http://www.nilu.no
Norwegian Meteorological Institute	http://www.met.no
Norwegian Polar Institute	http://npweb.npolar.no
Norwegian University of Life Sciences	http://www.umb.no
Norwegian Institute of Marine Research	http://www.imr.no
Norwegian Forest and Landscape Institute	http://www.skogoglandskap.no/
Norwegian School of Management	http://www.bi.no
Norwegian University of Science and Technology	http://www.ntnu.no
Norwegian Water Resources and Energy Directorate	http://www.nve.no/
Tromsø University	http://www2.uit.no
University of Bergen	http://www.uib.no
University of Oslo	http://www.uio.no
University Centre in Svalbard	http://www.unis.no

SWEDEN

Chalmers University of Technology	http://www.chalmers.se
Forestry Research Institute of Sweden	http://www.skogforsk.se
Geological Survey of Sweden	http://www.sgu.se
Karlstad University	http://www.kau.se
Linköping University	http://www.cspr.se
Luleå University of Technology	http://www.ltu.se
Lund University	http://www.lu.se
Mid Sweden University	http://www.miun.se
Mälardalen University	http://www.mdh.se
Royal Institute of Technology	http://www.kth.se
Stockholm Environment Institute	http://www.sei.se
Stockholm University/	http://www.su.se
Bert Bolin Centre for Climate Research	http://www.bbcc.su.se
Swedish Environmental Research Institute	http://www.ivl.se
Swedish Hydrological and Meteorological Institute/	
Rosby Centre for Climate Research	http://www.smhi.se
Swedish University of Agricultural Sciences	http://www.slu.se
Umeå University	http://www.umu.se
University of Gothenburg	http://www.gu.se
University of Kalmar	http://www.hik.se
Uppsala University	http://www.uu.se
Örebro University	http://www.oru.se

APPENDIX B

ADDITIONAL INFORMATION ABOUT REFERENCE GROUP, SURVEY AND WORKSHOP

Reference group

The reference group received and commented on a preliminary outline of this publication and an early draft of the publication. The members of the reference group were also given the opportunity to comment on the final version before it was sent to print. Members of the reference group were:

- Danish Agency for Science, Technology and Innovation, Morten Wied
- Icelandic Meteorological Office, Halldór Björnsson and Tómas Jóhannesson
- Nordic Council of Ministers, Fredrik Melander
- Nordic Council of Ministers, Marianne Neraal
- The Research Council of Norway, Jostein Sundet
- The Swedish Research Council, Jonas Björck
- Turku School of Economics, Jyrki Luukkanen
- University of Iceland, Aslaug Geirsdóttir
- University of Kuopio, Ari Laaksonen

Survey and workshop

In the preparation of this report, we received input from the scientific community and the reference group in three steps.

1. When preparing the outline of this report, we sent out an e-mail to some of the Nordic contributors to the IPCC's fourth assessment report, asking two simple questions:
 - What do you consider to be the most significant current or former Nordic research projects within climate change?
 - What do you consider to be the most significant research results obtained by Nordic research environments within climate change?
2. Based on input from the initial questions to the IPCC authors, a more detailed survey was carried out via telephone or e-mail. The institutions listed below answered the survey, as did members of the reference group:
 - Bjerknes Centre for Climate Research
 - CICERO
 - Danish Meteorological Institute (Danish Climate Centre)
 - Technical University of Denmark (DTU)
 - Finnish Environment Institute (SYKE)
 - Norwegian Meteorological Institute
 - Swedish Meteorological and Hydrological Institute (SMHI)
 - The University of Copenhagen
 - Helsinki University
 - The University of Oslo
 - Vestlandsforskning

Some of these interviews were carried out in February 2009 and others in May 2009. The questionnaire included the following questions:

- What research areas would you group under the heading “climate change research”?
 - In what areas of climate change research would you say that the Nordic countries have a high international standing?
 - Which Nordic climate change research centres would you say are most prominent?
 - Which Nordic climate change researchers would you say are the most prominent?
 - Could you give examples of important research results obtained in Nordic research environments?
 - What are the most important research areas related to climate change in your organisation? (where relevant)
 - Are there any specific fields/areas where you would say that your organisation has a high international standard?
 - Can you give examples of specific researchers and important research results from your organisation related to this/these fields?
 - Can you give examples of research results and research areas with specific relevance for developing countries?
 - How would you characterise Nordic cooperation in climate change research and Nordic participation in international research projects?
 - Looking to the future, in what areas will the need for new research be most imperative, and what research areas should be in focus in the Nordic countries research strategy?
3. An early draft of this publication was discussed at a workshop on June 17, 2009, with the following participants:
- Ellen Margrethe Basse, Aarhus University
 - Simone Heinz, NordForsk
 - Colin Jones, SMHI/Rosby Center for Climate Research
 - Antti Lauri, University of Helsinki
 - Marianne Neraal, Nordic Council of Ministers
 - Annemarta Strand Mugaas, Mandag Morgen
 - Jostein K Sundet, Norwegian Research Council
 - Michael Andersson, NordForsk
 - Anders Clarhäll, Swedish Research Council
 - Fredrik Melander, Nordic Council of Ministers
 - Markku Rummukainen, SMHI/Mistra-SWECIA
 - Linda Runesson, Mandag Morgen
 - Sanna Sorvari, University of Helsinki
 - Morten Wied, Danish Agency for Science, Technology and Innovation
 - Harry Zilliacus, NordForsk

APPENDIX C

LIST OF ACRONYMS AND ABBREVIATIONS

ACCENT - Atmospheric composition change - European Network of Excellence
ACOBAR - Acoustic technology for observing the interior of the Arctic Ocean
ADAM - Adaptation and Mitigation Strategies: supporting European climate policy
ALARM - Assessing Large Scale Environmental Risks for Biodiversity with tested Methods
AOSB - Arctic Ocean Sciences Board
BACCI - Centre on Biosphere-Aerosol-Cloud-Climate Interactions
BALTEX - The Baltic Sea Experiment
BaltCICA - Climate Change: Impacts, Costs and Adaptation in the Baltic Sea Region
BBCC - Bert Bolin Centre for Climate Research
BCCR - Bjerknes Centre for Climate Research
BIAC - Bipolar Atlantic Thermohaline Circulation
BNI - Baltic Nest Institute
CarboAfrica - Quantification, understanding and prediction of carbon cycle and other GHG gases in Sub-Saharan Africa
CarboEurope - Assessment of the European Terrestrial Carbon Balance
CARBOOCEAN - Marine carbon sources and sinks assessment
Carbo-North - Quantifying the carbon budget in Northern Russia: past, present and future
CAR-ES - Centre of Advanced Forest Research on Environmental Services
CIENS – Centre for Interdisciplinary Environmental and Societal Research
CIRCLE - Climate Impact Research Coordination for a Larger Europe
CITYZEN - Megacity - zoom for the environment
CLiC - Climate and Cryosphere
CLIM-ECO - Climate Variability in NW Europe During the Past 4000 Years and its Ecological Consequences
Clipore - Climate Policy Research Programme
CLIVAR - Climate Variability and Predictability
COP15 - United Nations Climate Change Conference in Copenhagen ,December 2009
CORDEX - Coordinated Regional Downscaling Experiment
DAMOCLES - Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies
DIVERTAS - International Programme on Biodiversity
DMI - Danish Meteorological Institute
DTU - Technical University of Denmark
ECMWF - European Centre for Medium-Range Weather Forecasts
ECRU - Environmental Change Research Unit
ENSEMBLES - ENSEMBLE-based Predictions of Climate Changes and their Impacts
EPOCA - European Project on Ocean Acidification
ERA - European Research Area
ERC – European Research Council
ESSP - Earth System Science Partnership
FICCA - Climate Change; governance, mitigation and adaptation
FMI - Finnish Meteorological Institute
FOI - Swedish Defence Research Agency
FOCALI - Forest, Climate & Livelihood Research Network
FORMAS - Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
GCOS - Global Climate Observing System
GECHS - Global Environmental Change and Human Security
GEUS - Geological Survey of Denmark and Greenland
GEWEX - Global Energy and Water Cycle Experiment
GLP - Global Land Project
GOOS - Global Ocean Observing System
GTOS - Global Terrestrial Observing System
HYACINT - Hydrological Modelling for Assessing Climate Change Impacts at different Scales
IASC - International Arctic Sciences Committee
IASSA - International Arctic Social Sciences Association

IGBP - International Geosphere-Biosphere Programme
 IHDP - International Human Dimensions Programme on global environmental change
 IMAGES - International Marine Past Global Changes Study
 IMO - International Maritime Organisation
 IMO – Icelandic Meteorological Office
 IMR – Icelandic Institute for Meteorological Research
 ICOS – Integrated Carbon Observation System
 IOC - International Oceanographic Commission
 IPCC - Intergovernmental Panel on Climate Change
 IPY - International Polar Year
 ISTO - Finnish Research Programme on Adaptation to Climate Change
 LRT - Land Restoration Training programme
 MAVERIC - Map-based assessment of vulnerability to climate change employing regional indicators
 MEGAPOLI - Megacities: emissions, urban, regional and global atmospheric pollution and climate effects, and integrated tools for assessment and mitigation
 MILEN - Environmental change and sustainable energy
 MISTRA - The Foundation for Strategic Environmental Research
 NECC - Nordic Centre for Studies of Ecosystem Carbon Exchange and its Interactions with the Climate
 NEEM - The North Greenland Eemian Ice Drilling
 NERI - the National Environmental Research Institute
 NMI - Norwegian Meteorological Insitute
 NORADAPT - Community Adaptation and Vulnerability in Norway
 NORIA - Nordic Research and Innovation Area
 NORKLIMA - Climate change and impacts in Norway
 PAGES - Past Global Changes
 PLAN - The Potentials of and Limits to Adaptation in Norway
 PRUDENCE - Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and Effects
 SAON - Sustained Arctic Observing Networks
 SEI - Stockholm Environment Institute
 SUM – Centre for Development and Environment
 SYKE - Finnish Environment Institute
 TOLERATE - Towards Levels of Required Adaptation to Cope with Extreme Weather Events
 WCRP - World Climate Research Programme
 WMO - World Meteorological Organisation

Endnotes

- 1 Produced by the Danish Royal School of Library and Information Science, published by the Ministry of Science, Technology and Innovation in the document “Mapping of climate research in Denmark” (March 2009).
- 2 Utarbeidet av Danmarks Biblioteksskole, utgitt av Ministeriet for Videnskab, Teknologi og Udvikling “Mapping of climate research in Denmark” (March 2009).
- 3 Source: Millimeterpress
- 4 IPCC (2007) “Climate Change 2007: Synthesis Report”, p. 26
- 5 <http://www.nordicenergy.net/>
- 6 Fourth version from 2005/2006
- 7 Produced by the Danish Royal School of Library and Information Science. Published by the Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy “Mapping of climate research in Denmark” (March 2009).
- 8 Source: “Mapping of climate research in Denmark” (March 2009). Produced by the Danish Royal School of Library and Information Science, published by the Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy.
- 9 Source: “Mapping of climate research in Denmark” (March 2009). Produced by the Danish Royal School of Library and Information Science, published by the Ministry of Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy.
- 10 Danish Ministry of Science, Technology and Innovation (2008) “RESEARCH2015 – A Basis for Prioritisation of strategic Research”
- 11 Koordineringsenhed for forskning i klimatilpasning (2009) “Klimatilpasning – 5 centrale forskningsstemaer”
- 12 DKK 43 million. (All currency conversions in this document are based on exchange rates in August 2009.)
- 13 Ministry of Agriculture and Forestry of Finland (2005) “Finland’s National Strategy for Adaptation to Climate Change”
- 14 Statsrådets kansli (2009) “Statsrådets framtidsredogörelse om klimat- och energipolitiken: vägen till utsläppssnålt Finland”, Statsrådets kanslis publikation 29/2009
- 15 Umhverfissráðuneytið (2008) “Hnattrænar loftslagsbreytingar og áhrif þeirra á Íslandi – Skýrsla vísindanefndar um loftslagsbreytingar”
- 16 Umhverfissráðuneytið (2009) “Möguleikar til að draga úr nettóútstreymi gróðurhúsalofttegunda á Íslandi, Skýrsla Sérfræðinganeftdar”
- 17 The Research Council of Norway (2006) “Nasjonal handlingsplan for klimaforskning”
- 18 The Research Council of Norway (Oct 2008) “Klimaforliket: Opptrappingsplan for klimaforskning - første innspill fra Forskningsrådet ad volum og innretning”. (The numbers do not include renewable energy and carbon capture and storage.)
- 19 Regeringen (2008) “Ett lyft för forskning och innovation”
- 20 SEK 1.2 billion
- 21 “Sweden’s fourth Communication on Climate Change” (2005), p. 100
- 22 In collaboration with the Danish Ministry of Climate and Energy, University of Copenhagen, the Technical University of Denmark, the Geological Survey of Denmark and Greenland.
- 23 United Nations World Commission on Environment and Development (1987) “Report of the World Commission on Environment and Development: Our Common Future”
- 24 The Linné grant is allocated by the Swedish Research Council and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning. The grant has been established with the goal of increasing Sweden’s competitiveness by creating strong groups for basic research.
- 25 www.icos-infrastructure.eu
- 26 “Thermohaline” refers to the temperature (thermo-) and dissolved salts (-haline) in ocean water. Thermohaline circulation is a slow and deep movement of water which is part of the large-scale ocean circulation.
- 27 <http://www.ink.su.se/pub/jsp/polopoly.jsp?d=4044&a=13948>
- 28 A project within the “International Geosphere-Biosphere Programme” (IGBP), see Chapter 6
- 29 Earth System interactions: enhancing capabilities for the prediction of global, regional and local climate change - a Nordic window of opportunity (2009)
- 30 Developed by European Centre for Medium-Range Weather Forecasts (www.ecmwf.int)
- 31 ECMWF Annual Report 2008

32 IPCC (2007), "Climate Change 2007: Synthesis Report,"
 33 European Commission (2009) "Integrated assessment of the European and North Atlantic Carbon Bal-
 ance – key results, policy implications for post 2012 and research needs"
 34 The project runs until the end of 2009.
 35 European Commission (2009) "Integrated assessment of the European and North Atlantic Carbon Bal-
 ance – key results, policy implications for post 2012 and research needs" p. 105
 36 Ibid, p. 42
 37 From the Atlantic coast to the Ural Mountains
 38 European Commission (2009) "Integrated assessment of the European and North Atlantic Carbon Bal-
 ance – key results, policy implications for post 2012 and research needs" p.10
 39 European Environment Agency (2008) "Impacts of Europe's changing climate - 2008 indicator-based
 assessment"
 40 Key vulnerabilities as described in the report CIRCLE-ERA NET (2008) "Climate Impact Research Coordination for a Larger Europe"
 41 Key vulnerabilities as described in the report CIRCLE-ERA NET (2008) "Climate Impact Research Coordination for a Larger Europe"
 42 The BACC Author Team (2008) "Assessment of Climate Change for the Baltic Sea Basin"
 43 CIRCLE (2008) "Report on the current state of National Research Programmes on Climate Change
 Impacts and Adaptation in Europe, Extended Country Report – Issue 2"
 44 Tyndall Centre for Climate Change Research (2009) "Adaptation and Mitigation Strategies: Supporting
 European Climate Policy - The Final Report from the ADAM Project"
 45 Other partners are the Royal Institute of Technology, Umeå University and Uppsala University
 46 PEER (2009) "Climate Policy Integration, Coherence and Governance"
 47 "Moving Ahead with REDD: Issues, Options and Implications" (2008)
 48 Forskning om Forskning (nr 1 2009) "Nationella särdrag i nordisk publiceringsutveckling 1998–2006",
 p.8-9
 49 Source: "Mapping of climate research in Denmark" (March 2009). Produced by the Danish Royal School
 of Library and Information Science, published by the Ministry of Science, Technology and Innovation,
 Coordination Unit for Research in Climate Change Adaptation and the Ministry of Climate and Energy.
 50 Carried out by the Danish Royal School of Library and Information Science. Published by the Ministry of
 Science, Technology and Innovation, Coordination Unit for Research in Climate Change Adaptation and
 the Ministry of Climate and Energy "Mapping of climate research in Denmark" (March 2009).
 51 ACIA (2005) "Impacts of a warming Arctic - highlights", p. 5
 52 The European Commission (2009) "FP7 Subscription, Performance, Implementation during the first two
 years of operation 2007-2008"
 53 Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden
 54 European Commission (2009) "Communication from the Commission to the European Parliament, the
 Council, the European Economic and Social Committee and the Committee of the Regions concerning
 the European Union Strategy for the Baltic Sea Region"
 55 <http://www.oecd.org/dataoecd/48/34/42459170.pdf>
 56 Danish Development Research Network, Danish Water Forum and the Danish Research Network for
 International Health
 57 Thomas Birk (2008) "Overview of Danish research competences and research projects - with regard to
 climate change impacts, mitigation and adaptation in developing countries"
 58 Megacities: Emissions, urban, regional and Global Atmospheric Pollution and climate effects, and Inte-
 grated tools for assessment and mitigation
 59 <http://www-abc-asia.ucsd.edu>
 60 Thomas Birk (2008) "Overview of Danish research competences and research projects - with regard to
 climate change impacts, mitigation and adaptation in developing countries"
 61 IPCC (2009) "Chairman's vision, AR5 Scoping Meeting ;Venice, Italy, 13-17 July 2009"
 62 PEER (2009) "Climate Policy Integration, Coherence and Governance"
 63 PEER (2009) "Europe Adapts to Climate Change - Comparing National Adaptation Strategies"
 64 PEER (2009) "Europe Adapts to Climate Change - Comparing National Adaptation Strategies", p. 67
 65 IPCC (2009) "Chairman's vision, AR5 Scoping Meeting ;Venice, Italy, 13-17 July 2009"
 66 World Meteorological Organisation (2009) "The State of Polar Research"
 67 The European Commission C(2009) 5893 of 29 July 2009, "FP7 Cooperation Work Programme 2010:
 Environment (including climate change)"

The NordForsk policy brief “Nordic Climate Change Research” describes the focus and strengths of Nordic climate change research, and encompasses both collaborative Nordic research efforts and activities carried out in each of the Nordic countries. Paleoclimatology, climate modelling, atmospheric research and oceanography stand out as particular competence areas in the Nordic countries. Nordic climate change research is also conducted in areas involving regions, sectors and ecosystems of strategic importance to the Nordic countries, such as the Arctic region, the Baltic Sea, agriculture, forests, wetlands and marine ecosystems. Nordic climate change research is described on the basis of categories used by the Intergovernmental Panel of Climate Change (IPCC):

- Climate change – How is the climate changing?
- Climate change drivers – Why is the climate changing?
- Impacts and vulnerabilities – What are the consequences of climate change?
- Adaptation and mitigation – What are appropriate responses to climate change?

Based on those categories, the report describes areas of strengths, research projects and results of Nordic climate change research. As the task of advancing understanding of climate change is a global one, international cooperation within climate change research is widespread. The report gives a picture of the involvement of Nordic climate change researchers in European and other international projects. Nordic researchers are also actively engaged in a wide range of climate-related research relevant to developing countries, such as regional climate modelling, water and resource management, agricultural research, research on international climate agreements and funding mechanisms for climate mitigation and adaptation in the developing world. The report concludes with a chapter giving an outline of some of the current trends that might influence climate change research in the years to come.