Bjerknes Centre for Climate Research 2013

Bjerknes Centre
for Climate Research

An aerial photo of the ocean south of Spitsbergen in April 2013, looking towards the Barents Sea. In the distance, freshly formed sea ice whirls with the ocean currents. Clouds are formed in the lower part of the photo, as warm Atlantic water gives up heat and moisture to the atmosphere.

PHOTO: JAN EVEN ØIE NILSEN

NERSC
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uni Research

Statement from the board

The board is pleased with the performance of the Bjerknes Centre during 2013; both in terms research activities, volume of scientific output and contribution to the international climate research. Scientists affiliated with the Bjerknes Centre succeeded in acquiring an unprecedented number of research grants from the Research Council of Norway, the Nordic Top Initiatives and the European Commission. This will enhance and expand personnel and scientific activities in the coming years.

The termination of the funding to the Centre of Excellence in 2012 and the new funding from the Ministry of Education and Research to the Centre for Climate Dynamics prompted a revision of the governance of both organisations. The board looks forward to the emerging single and simplified governance structure.

The Bjerknes Centre is an umbrella organisation involving the University of Bergen, Uni Research, the Institute of Marine Research and the Nansen Environmental and Remote Sensing Center, in skilful cooperation for more than a decade. This collaboration has produced high quality – and some world leading – science, acknowledged by its national and international peers. The board is thus convinced that the grounds are set for continuing success in the new phase of the Bjerknes Centre.

Nyksund, Vesterålen
A beautiful backdrop for the Advanced Climate Dynamics Courses in August 2013.

PHOTO: **DAVID BATTISTI**

New governance and opportunities

TORE FUREVIK, DIRECTOR OF THE BJERKNES CENTRE FOR CLIMATE RESEARCH

After a decade as a national Centre of Excellence (CoE) under the leadership of Eystein Jansen, the Bjerknes Centre has evolved into a large scientific community with a strong national and international standing. With the CoE funding ending last year, 2013 marked the start of a new phase in the life of the Centre. The year was devoted not only to consolidating our position as a leading international climate research centre, but also to performing a structural reorganisation in light of the new funding from the government to the Centre for Climate Dynamics (SKD) in order to optimize existing resources and promote further growth in terms of scientific output. As a result, the Bjerknes Centre and SKD merged into a single governance structure consisting of a new director as well as a new board, leader group and research groups. One of my first tasks will be to lead the work towards a vision statement as well as the design of a new science and implementation plan for the Bjerknes Centre in the coming years.

This year has been exceptional in terms of science achievements, grant awards, research training, recruitment and outreach. The number of peer-review publications hit a record high. In terms of funding, Bjerknes scientists achieved the highest success rate in the centre's history during the last call from the NORKLIMA programme of the Research Council of Norway (RCN). Nine out of thirteen grants, encompassing more than two-thirds of the funds available were awarded to the partners of the Bjerknes Centre. Additional funding included six grants under RCN´s funding scheme for independent basic research – FRIPRO – (including a "Young Research Talent" award), one grant from the Nordic Top Initiatives on the impact of future cryospheric changes, and one grant from EU´s FP7 on prediction of tropical Atlantic climate. And last, but not least, the Bjerknes Centre teamed with colleagues from Denmark to win Norway´s first European Research Council Synergy grant – "Ice2Ice" – a 12.5 million Euro research project over five years.

There are close to 30 PhD candidates and a similar number of post-doctoral fellows associated with the Bjerknes Centre, both in in-kind positions at the partner institutions or in positions funded through research projects. Further new positions will be associated in 2014 thanks to the substantial new external funding mentioned above. These young scientists will be provided with a stimulating environment through the activities of the Norwegian Research School for Climate Dynamics (ResCLIM) as well as through a partnership programme in climate research with institutions from Canada and the USA. These include various funding schemes, annual summer schools, and regular courses in geophysical fluid dynamics, sea ice dynamics, statistics, academic writing, communication, and much more. An outstanding example of what can be accomplished is the international ClimateSnack community that has been developed by Mathew Reeve.

In the international climate arena, the Bjerknes Centre made major contributions to IPCC´s Fifth Assessment Report (AR5). With colleagues in Oslo we provided model scenarios from the Norwegian Earth System Model (NorESM), placing Norway among the few European countries capable of delivering state-of-the-art climate modelling data to the assessment. Three Bjerknes scientists were lead authors; two review editors and four contributing authors. While the overall human influence on the climate system now is clear, this winter's flooding in England and record high temperatures, droughts and wild fires in many parts of Norway are indicators that we still have work to do before we understand all aspects of climate change.

Objectives and Research

The Bjerknes Centre for Climate Research (BCCR) focuses on the natural science of climate change and is a prime provider of science-based knowledge on global change to society. It is the largest climate research centre in the Nordic countries.

BCCR will continue to be at the international research front by virtue of its unique strength: the combination of observations, theories and modeling in a multi-disciplinary research fashion. For this, the BCCR community involves marine, terrestrial, and atmospheric scientists aiming to understand the complexity of the dynamics of the climate system in the past, present and future. In addition, BCCR coordinates the national research training in climate dynamics and aims at becoming the first port of call of global surface marine CO_2 data and related variables.

Bjerknes´ new governance prompted the revision of the key areas of research as well as the organisation of the research groups (RG). The RGs are in charge of the implementation of the centre´s scientific strategy and so the former five teams were then re-arranged into seven new groups.

Key areas of research

- Natural variability of the climate system and man-made climate change
- Identification of key processes of the climate system in the northern high-latitudes
- Earth System modeling and regional models for climate scenarios on global to local scales
- Development of climate prediction capacities on seasonal to decadal scales
- Ocean and land biogeochemistry
- Reconstruction and modeling of past climates from millennial to glacial time scales

Research groups

The research groups are teams composed of scientists, PhD candidates and technical staff that implement the Centre´s key areas of research. These are:

1. Climate model development and projections
2. Climate predictions from global to regional scales
3. Carbon cycle and biogeochemistry
4. Large-scale atmosphere-ocean dynamics
5. Atmosphere, cryosphere and ocean processes
6. Natural climate variability
7. Past climate dynamics

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Our climate footprints change the planet

The footprints of mankind leave ever more imprints on the climate, according to the Fifth Assessment Report (AR5) from the Intergovernmental Panel on Climate Change (IPCC). Interview with Prof. Eystein Jansen, Lead Author of the chapter "Information from Paleoclimatic Archives" in the IPCC AR5 report.

BY **JILL JOHANNESSEN** (TRANSLATION BY SVERRE OLE DRØNEN AND BEATRIZ BALINO)
SHORTENED VERSION, FULL TEXT AVAILABLE AT WWW.BJERKNES.UIB.NO

↑ The front page of the IPCC WG1 report is from the Folgefonna glacier from the autumn of 2006, a year with extensive melting all over the glacier.

"If we are to stay below the "2-degree" target, we must start transforming into a renewable energy society now."

This was the clear message from Prof. Jansen upon the release of IPCC AR5 report . AR5 provides the most updated and comprehensive knowledge of changes of the climate system and creates the scientific basis for climate policy over the next six years, both in Norway and internationally. The Bjerknes Centre is responsible for the development and implementation of the Norwegian Earth System model (NorESM), which provided global climate projections to the report.

"A very important discovery is that the footprint of our greenhouse gas emissions is very evident in the climate system. The human impact upon the temperature development is clear on every continent, except Antarctica, but also on a number of other factors", Prof. Jansen says, listing:

- Rise in sea level.
- The chemical composition of the ocean (for example acidification and salinity).
- Changing ice/snow conditions (for example melting of glaciers, retreating Arctic sea ice and the snow cover on land in the northern hemisphere).
- Heat waves.
- Changes of the ozone layer.
- Changes in precipitation patterns (significant increase in precipitation and of extreme precipitation events in the mid-to high-latitude northern hemisphere).

Global warming in a 2000-year perspective

The inclusion of major reconstructions of past climates from a wide variety of sources is novel in the present report. These are sources such as tree rings, stalagmites, ice cores, sediments cored from lakes and the sea floor. They enabled scientists to identify the emergence of a significant human component of warming in recent decades on major continents such as Asia and South America.

"Past climate reconstructions from all continents, with the exception of Africa where there is a scarcity of data, clearly show that today's global warming is unique in a 2,000 year perspective", Prof. Jansen says.

The IPCC has also updated estimates of global and regional rise in average sea levels. If greenhouse-gas emissions continue at present levels, then it is expected that sea level may rise as much as one meter within this century. And even if emissions are reduced to meet the 2-degree target, sea level will still continue to rise, by as much as 50 cm, by the end of the century.

According to Jansen, we have just seen the beginning:
"This report shows that what we have seen so far is just the beginning of a long-term rise in sea level which, on a time scale of centuries, will reach several meters. There is clear evidence of a long-term, several meters rise in sea level from studies of past climates with temperatures not much higher than those we have now."

"A great responsibility resting on the shoulders of our generation"

Today, the pace of changes in the drivers and in several responses is as much as 20 times faster than what we have reconstructed for climate changes in the past. The planet is under a major pressure not experienced in the time humankind has existed as a species. There is nothing in the past comparable to the present situation.

"The choices we make in the next couple of decades will determine how much risk we impose on future generations. Vast resources will be required to adapt to and repair the effects of a climate in constant flux."

From left: Peter Thorne, Christoph Heinze and Eystein Jansen

Contributing to the IPCC Fifth Assessment Report

Eystein Jansen, Peter Thorne and Christoph Heinze have been respectively lead authors and review editor in the IPCC Working Group 1.

Several researchers at the Bjerknes Centre have contributed to the IPCC, Working Group 1 report "the Physical Science Basis". The Bjerknes Centre also performed global climate model simulations in support of the IPCC report. The Bjerknes authors have contributed with input on several topics including paleoclimates, observations, and carbon cycle. Trond Dokken , Jerry Tjiputra (both Uni Research) and Camille Li (UiB) were contributing authors.

Peter Thorne, senior scientist at the Nansen Centre was lead author of Chapter 2, which is concerned with observations. Thorne lists up some important findings:

"It is certain that radiatively active trace gases (Carbon Dioxide, Methane etc.) are overall increasing. It is also certain that over the last 150 years surface temperatures have risen. Each of the last three decades have been significantly warmer in turn that all decades that preceded them in the instrumental record. Corroborating evidence for a world that has warmed is provided by changes in other closely related climate system properties."

Warming evidence is clear

According to Thorne, the evidence of a world that has warmed is clear from high in the atmosphere to deep in the oceans.

"It has been verified many times over. In a warming world we would expect the troposphere (the lowest atmosphere where for example clouds occur) and the ocean to warm, the atmospheric water content to increase, sea level to rise and for glaciers, sea ice and spring snow cover to decrease. All these things have indeed occured and have been confirmed by multiple independent analyses from multiple groups of analysts in very many countries."

Yet, observed changes in some things are less certain: *"Changes in precipitation are less well understood as are changes in many climate extremes such as tropical cyclones. Changes in circulation seem to be largely cyclical in many cases. The exception is emerging evidence for a broadening of the tropical circulation which appears to be a robust feature."*

Reduced uptake capacity

Christoph Heinze, Professor of chemical oceanography at UiB has been review editor of Chapter 6, "Carbon and Other Biogeochemical Cycles". This chapter deals primarily with the budgets of greenhouse gases and the feedback between these gases and the climate system.

Compared to previous assessment reports, now the very important greenhouse gases nitrous oxide (N_2O) and methane (CH_4) have been considered in more detail, next to carbon dioxide (CO_2).

"The reason for this is that the observational data bases for these gases in the different Earth system compartments, such as atmosphere, land, ocean, could be extended and that predictive models are starting to include these gases as well" Heinze states.

A reduced uptake capacity for anthropogenic carbon was revealed by the two models which included the coupling of nitrogen and carbon cycles on land in their process descriptions. This is because the CO_2 induced stimulation of carbon uptake by land plants is then limited also by available nitrogen.

According to Heinze, this picture can change again, when reactive nitrogen sources due to anthropogenic activity are included in more detailed computations.

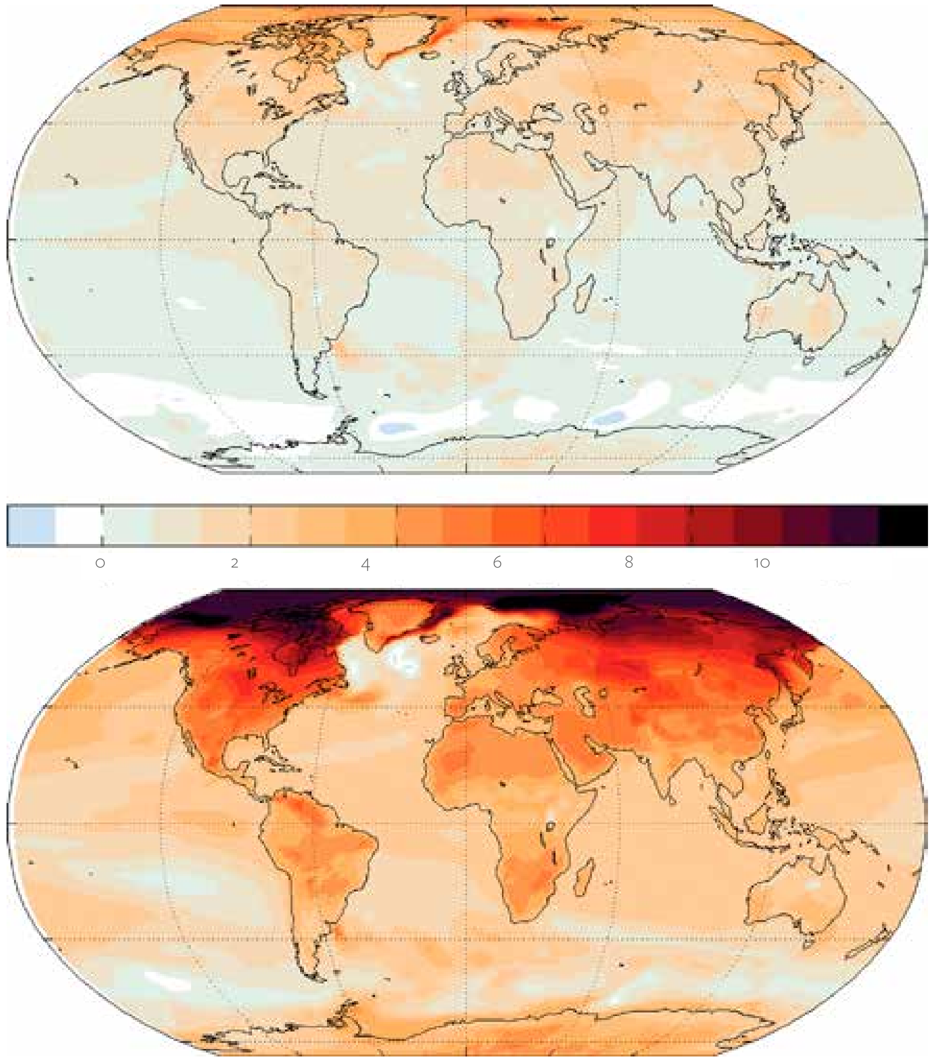
Fifteen years of global climate modelling

The Bergen Climate Model was the admission ticket to the Bjerknes Centre to join the league of European expert modelling groups to deliver model scenarios to the IPCC AR4. Since then Bjerknes has lead the nationally coordinated effort towards the development of the Norwegian Earth System Model- NorESM

BY **HELGE DRANGE & ASGEIR SORTEBERG**

NorESM is the result of 15 years of global climate modelling activities in Norway, whose main contributors have been the Bjerknes Centre for Climate Research, the University of Bergen, the Norwegian Meteorological Institute, and the University of Oslo.

NorESM is based on the Community Climate System Model operated at the National Center for Atmospheric Research, Boulder, Colorado,



Simulated change in mean surface air temperature (K) with NorESM from 1976–2005 to 2071–2100. Upper panel represents an emission scenario with strongly reduced greenhouse gas emissions (RCP2.6), where the lower pale represents a "business-as-usual" emission scenario (RCP8.5). Figure from Iversen et al. (2013).

but differs from the latter by, in particular, an ocean general circulation model developed in Bergen and chemistry-aerosol-cloud-radiation interaction schemes developed in Oslo.

NorESM is one of several global climate models that contributed to the IPCC AR5. For this, a total of about 5000 model years have been run, covering the years 1850-2100 and with one integration extending to year 2300. Three versions of the model is available, one of which includes fully dynamic carbon cycle.

As of March 2014, results from NorESM have been used in more than 200 publications in international refereed journals, making NorESM one of the most frequently used climate models. A special issue was established in the journal Geophysical Model Development, describing the basic development, validation, scientific analyses, and climate scenarios made with NorESM.

Over the past three years, the grant to SKD has supported the development of NorESM by securing the core personnel previously responsible for the Bergen Climate Model. In addition, it funded lead and review authors affiliated with the Bjerknes Centre involved in the writing process of the IPCC AR5.

Dedicated SKD-funding has been tailored towards analysis of the global carbon cycle; ocean processes and the role of sea ice in the Arctic; glacial climate states; planetary boundary layer processes; North Sea regional assessment of IPCC AR5 model runs; response of storm tracks to global warming; and changes and variability in the Indian monsoon. These activities, lead by Asgeir Sorteberg at UiB, were finalized in 2013 and the results will be presented in a dedicated publication.

Iversen, T., M. Bentsen, I. Bethke, J. B. Debernard, A. Kirkevåg, Ø. Seland, H. Drange, J. E. Kristjansson, I. Medhaug, M. Sand, and I. A. Seierstad (2013). The Norwegian Earth System Model, NorESM1-M - Part 2: Climate response and scenario projections, Geosci. Model Dev., 6, 389-415, doi:10.5194/gmd-6-389-2013

New CO_2 emission record in human history

The 2013 report shows that global emissions of carbon dioxide from the combustion of fossil fuels will reach 9.8 gigaton carbon (GtC) in 2013, which is 61 per cent above the emissions in 1990.

BY JILL JOHANNESSEN

"The Global Carbon Project" provides an annual analysis of global carbon emissions and sinks, incorporating data from multiple research institutes from around the world. The Bjerknes Centre contributes to this report by providing estimates of trends and variability of ocean CO_2 uptake based on model results, observations and by assembling a database of marine observations.

– *This year's report also shows that atmospheric carbon dioxide (CO_2) levels increased in 2012 at a faster rate than the average over the past 10 years, due to a combination of continuing growth in emissions and a decrease in land carbon sinks from a very high level in the previous year,* says Abdirahman Omar, one of the three contributing co-authors at the Bjerknes Centre.

Coal continues to dominate

The figures to the right shows yearly development in CO_2 emissions in GtC, in which coal has had the strongest growth. It also indicates that the development in Chinese emissions is a main cause for this strong growth in coal. Chinese emissions grew by 5.9 % in 2012, which constitutes 70 % of the global increase in CO_2 emissions. Indian emissions increased 7.7 percent, which makes up for 20% of the global increase in CO_2 emissions. Carbon dioxide emissions in the USA continued their decline with minus 3.7 percent in 2012, which is caused mainly by a transition from coal to gas.

– *China's strong growth in emissions is largely due to increased use of coal, and has already reached the same level of emissions per capita as EU with 7 tons CO_2 per person. Even though green investments have started to take off in China, it is far from enough to weaken the CO_2 emissions growth,* says the former Director at the Bjerknes Centre, Eystein Jansen.

Hope is fading for limiting the warming to two degrees

Cumulative emissions of CO_2 from all sources (fossil fuels plus land use change) since 1870 will reach 550 GtC this year.

– *A continuation of the emissions growth trends observed since 2000 would place the world on a path to reach 2 degrees Celsius above pre-industrial times in 30 years, based on the mean of IPCC models,* says Jansen.

He also underlines the importance of moving toward a large-scale transition, away from not only coal but also other fossil-based energy sources.

Publication

Le Quéré, C., Peters, G. P., Andres, R. J., Andrew, R. M., Boden, T., Ciais, P., Friedlingstein, P., Houghton, R. A., Marland, G., Moriarty, R., Sitch, S., Tans, P., Arneth, A., Arvanitis, A., Bakker, D. C. E., Bopp, L., Canadell, J. G., Chini, L. P. Doney, S. C., Harper, A., Harris, I., House, J. I., Jain, A. K., Jones, S. D., Kato, E., Keeling, R. F., Klein Goldewijk, K., Körtzinger, A., Koven, C., Lefèvre, N., Omar, A., Ono, T., Park, G.-H., Pfeil, B., Poulter, B., Raupach, M. R., Regnier, P., Rödenbeck, C., Saito, S., Schwinger, J., Segschneider, J. Stocker, B. D., Tilbrook, B., van Heuven, S., Viovy, N., Wanninkhof, R., Wiltshire, A. and Zaehle, S. (2013): Global carbon budget 2013. *Earth System Science Data Discussions*, 6, 689–760, doi:10.5194/essdd-6-689-2013

1. Abdirahman Omar, research leader, Uni Research AS
2. Benjamin Pfeil, Data manager, UiB
3. Jörg Schwinger, researcher, UiB

➔ CO_2 emissions from fossil-fuel combustion and cement production for:

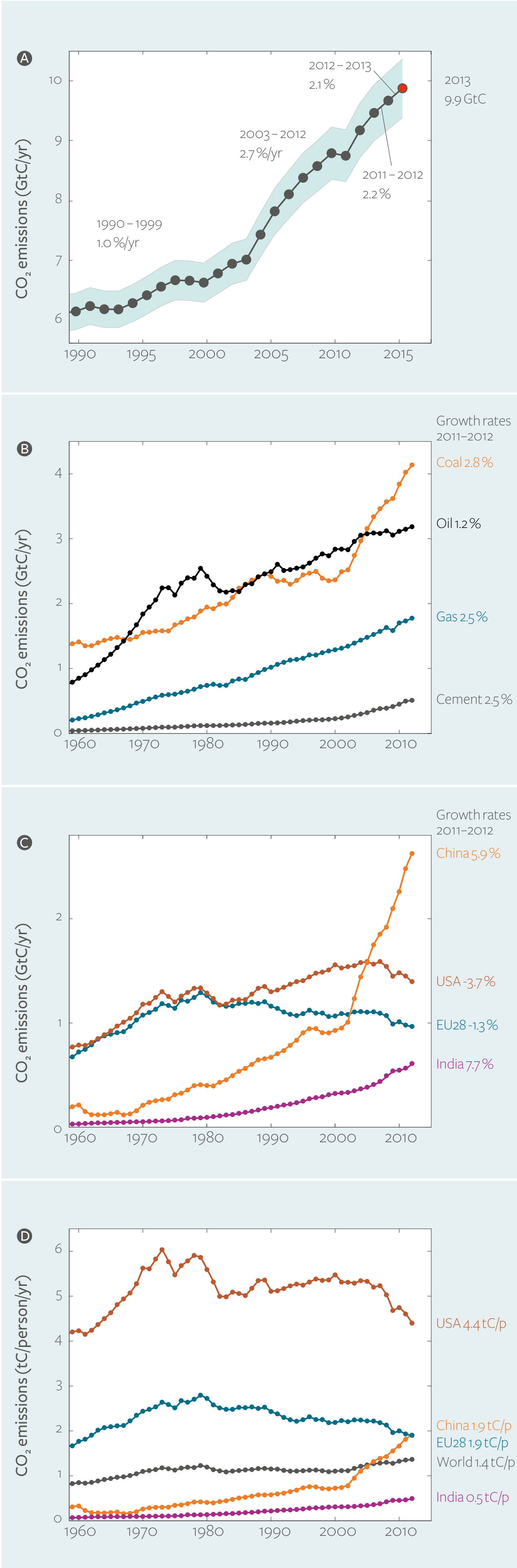
Ⓐ the globe

Ⓑ global emissions by fuel type, including coal (red), oil (black), gas (blue), and cement (purple)

Ⓒ territorial CO_2 emissions for the top three country emitters (USA – purple; China – red; India – green) and for the European Union (EU; blue in 2012)

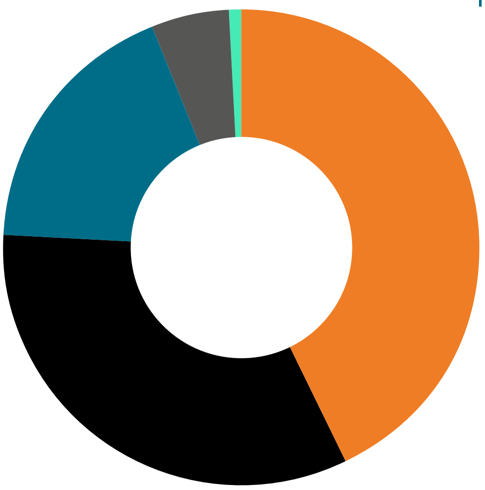
Ⓓ per-capita emissions for the top three country emitters and the EU.

Figures: Global Carbon Budget 2013. www.globalcarbonproject.org



In spite of a boom in renewable energy, coal continues to dominate energy development and many of the top country emitters have increased their coal dependency.

- Coal 43 %
- Oil 33 %
- Gas 18 %
- Cement 5.3 %
- Gas flaring 0.6 %



➔ The 2012 carbon dioxide emissions breakdown is coal (43%), oil (33%), gas (18%), cement (5.3%) and gas flaring (0.6%).

Lofoten. PHOTO: KERIM NISANCIOGLU

Low-pressure activity affects the Barents Sea heat budget

In a paper in Nature Communications, Vidar Lien, Frode Vikebø and Øystein Skagseth identify a mechanism that induces a cyclonic circulation anomaly along the slope encircling the northern Barents Sea shelf area. This circulation anomaly affects the relative strength of the two Atlantic Water branches towards the Arctic by enhancing the flow through the Barents Sea while weakening the branch flowing through the Fram Strait and along the Arctic continental slope. The cyclonic circulation anomaly is caused by wind-induced Ekman transport off the northern Barents Sea shelf and subsequent decrease in sea-surface height. The variability of the inflow to the Barents Sea may also affect the ecosystem, as nutrients are transported along with the warm waters.

Lien, V. S., Vikebø, F. B. and Skagseth, Ø. (2013): One mechanism contributing to co-variability of the Atlantic inflow branches to the Arctic. *Nature Communications*, 4, 1488, doi: 10.1038/ncomms2505.

A fresh look at the Gulf Stream's Arctic limb

The Norwegian Atlantic Current is an important component in Earth's balanced distribution of heat and freshwater, and a main contributor to regional climate. It is therefore a major concern how and to what extent this ocean current changes with climate, and vice versa. Tor Eldevik and Jan Even Øie Nilsen's paper in Journal of Climate shows that it is the heat that is decisive for the vigour of the Norwegian Atlantic Current. They have constructed a simple mathematical model rooted in 60 years of observations, and find that the Norwegian Atlantic Current is constrained by the amount of excess heat that it brings from the south. On the other hand, northern freshwater input explains the extent to which the return flow from the Norwegian Sea to the North Atlantic takes place in the surface or in the deep ocean. As a consequence, it is inferred that much of the observed decrease in Arctic winter sea-ice cover can be explained by increased poleward heat transport with the Norwegian Atlantic Current.

Eldevik, T. and Nilsen, J. E. Ø. (2013): The Arctic–Atlantic thermohaline circulation. *Journal of Climate*, 26, 8690–8705.

Bringing the North Pacific to life 14,000 years ago

As the world emerged from the last Ice Age, the North Pacific saw a sudden proliferation of tiny creatures such as phytoplankton and foraminifera. This brief, strong spike in biological productivity is observed in marine sediment cores throughout the region. Iron limits productivity in the subarctic Pacific, equatorial Pacific and Southern Ocean today, prompting the idea that the spike was caused by an influx of iron from the continental shelves as they were flooded during the deglaciation. A study in Nature Geoscience co-authored by Camille Li reveals that no evidence exists for an iron pulse from any source during the time of the productivity spike. The study attributes the spike to an increase in major nutrient supply from deep convection, followed by melt-water-induced stratification that relieved light limitation. The findings resolve conflicting ideas about the relationship between iron and biological productivity in the deglacial North Pacific, and have potentially important implications for geo-engineering efforts to slow climate change by seeding the ocean with iron.

Lam, P. J., Robinson, L. F., Blusztajn, J., Li, C., Cook, M. S., McManus, J. F. and Keigwin, L. D. (2013): Transient stratification as the cause of the North Pacific deglacial productivity spike. *Nature Geoscience* 6, 622–626.

On track to climate prediction

"How will the following winters be?"
This is a question we might answer in the future.

BY **FRANCOIS COUNILLON**

Vesterålen. PHOTO: KERIM NISANCIOGLU

At the Bjerknes Centre, researchers are exploring the potential for seasonal to decadal climate prediction. This is a field still in its infancy, and a first attempt was made public for the latest Intergovernmental Panel on Climate Change (IPCC) report. Apart from a few isolated regions, prediction skill was moderate, leaving room for improvement. In a new study published in Tellus A, seasonal-to-decadal prediction tested with an advanced initialisation method that has proven successful in weather forecasting and operational oceanography.

"Ordinary" climate projections are designed to represent the persistent change induced by external forcings. Such "projections" start from initial conditions that are distant from today's climate and thus fail to "predict" the year-to-year variability and most of the decadal variability, such as the pause (hiatus) in the global temperature increase or the spate of harsh winters in the northern hemisphere. In contrast, weather predictions rely entirely on the accuracy of their initial state as the influence of the external forcing is almost imperceptible.

For seasonal-to-decadal time scales, both the initial state and the external forcing influence the prediction. Starting a climate prediction from an initial state closer to the real climate is therefore necessary to yield a better prediction than by accounting only for external forcing. In our region of interest, decadal skill may be achieved by improving the representation of the heat content transiting into the Nordic Sea and in turn may influence the precipitation and temperature over Scandinavia.

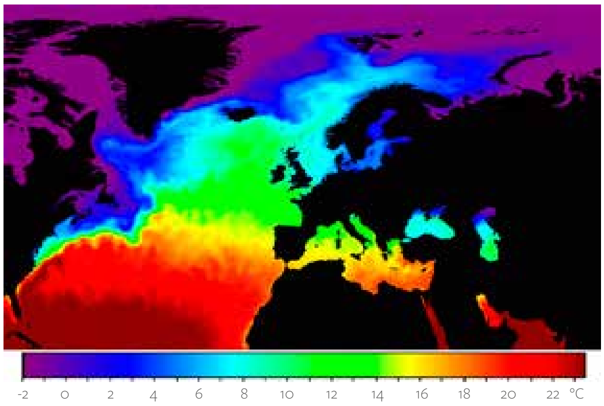
The method employed to initialise/correct a dynamical system is referred to as data assimilation. It estimates the initial state of a model knowing a set of sparse observations (much less than 1% of the ocean variables are observed). A relationship between the observations and the non-observed variables must be found to broaden the corrections. Furthermore, the corrections must satisfy the model dynamics to avoid abrupt adjustments during the forecast. The Ensemble Kalman Filter uses statistics from an ensemble of predictions to estimate the relationship between the observations and all variables for their correction. This method is computationally intensive as it requires parallel integrations of the model but it ensures that the relationship evolves with the system, and that the corrections satisfy the dynamics of the model.

The Norwegian climate prediction model (NorCPM) combines the Norwegian Earth System model (NorESM) with the Ensemble Kalman Filter. In time, we intend to perform retrospective decadal predictions (hindcasts) over the last century, to test the skill of our system on disparate phases of the climate and shed light on the relative importance of internal and external influences on natural climate variability, including the significance of feedback mechanisms. Sea-surface temperatures (SST) are the only observations available for such a long period of time and will be used for initialisation.

Our study investigates the potential skills of assimilating SST only, using an idealised framework, i.e. where the synthetic solution is taken from the same model at different times. This framework allows an extensive validation because the full solution is known and our system can be evaluated against the upper predictive skill (the case where observations were available absolutely everywhere). NorCPM demonstrated decadal predictability for the Atlantic meridional overturning and heat content in the Nordic Seas that is close to the model's limit of predictability. Although these results are encouraging, the idealised framework assumes that the model is perfect and lower skill is expected in a real framework. This verification is currently ongoing.

Counillon, F., Bethke, I., Keenlyside, N., Bentsen, M., Bertino, L. and Zheng, F.: Seasonal-to-decadal predictions with the Ensemble Kalman Filter and the Norwegian Earth System Model: a twin experiment. *Tellus A*, 2014, 66, 21074.

The North Atlantic Ocean drives the weather



➊ The image shows the North Atlantic sea surface temperature from satellites (January 2008), which clearly shows the Gulf Stream and North Atlantic Current. These are the regions where the ocean pumps large amounts of heat into the atmosphere that are important on decadal timescales (source image: NOC/UK Met-Office OSTIA data).

Jacob Bjerknes, the father of modern weather forecasting, suggested that there would be a connection between European weather and temperatures in the North Atlantic. Fifty years later, Bjerknes Centre helps to prove that Bjerknes was right in his prediction.

BY NOEL S. KEENLYSIDE

The last decade has brought a spate of hot summers and cold winters. The cause of these – natural variability or global warming – is debated. Persistent periods of extreme weather are not a new phenomenon for Europe. In particular, the 1940s also saw a series of cold winters and summer heat waves. At the same time, temperatures of the North Atlantic Ocean varied with a timescale of 70–80 years, and they were unusually warm in the 1940s, as they are now.

Bjerknes envisaged the ocean pumps

Are European weather and North Atlantic Ocean temperature linked? This question interested Jacob Bjerknes, and he was the first to postulate that the North Atlantic Ocean may drive changes in climate on these time scales. Based on limited data, Bjerknes, in a study published in 1967 argued that persistent warming and cooling periods of the North Atlantic could not be entirely explained by atmospheric changes, but may instead drive them.

The first observational proof

A study published in *Nature* provides the first observational proof for Bjerknes' conjecture. It provides a new estimate of turbulent surface heat flux for the North Atlantic from ship measurements extending back till 1880, using an innovative statistical algorithm.

Ocean and atmosphere communicate via turbulent heat flux, which transfers heat between the two. The scientists behind the study show that sea-surface temperature and turbulent heat flux co-varied over the Gulf Stream and its extension to the North Atlantic on longer timescales (see figure above). Specifically, they show that the atmosphere did not entirely drive the observed persistent warming and cooling periods. Rather the ocean may drive the atmosphere on these time scales.

Improved decadal forecasts

While the results do not prove that the North Atlantic influences European weather, they provide the first observational evidence that the ocean in this region can influence the atmosphere. This is an important step towards the realisation of climate prediction for the North Atlantic Sector, and follows in the spirit of the ground-breaking work of Bjerknes and other scientists from Bergen.

Gulev, S. K., Latif, M., Keenlyside, N., Park, W. and Koltermann, K. P. (2013): North Atlantic Ocean control on surface heat flux on multidecadal timescales. *Nature*, 499, 464–467.

Circulation changes in a warmer ocean

The study by Zhongshi Zhang, Kerim Nisancioglu and Ulysses Ninnemann published in Nature Communications in February 2013, suggests that the pattern of ocean circulation was radically altered in the past when climates were warmer. From the Great Barrier Reef in autumn 2013. PHOTO CHRISTOPH HEINZE

A Bjerknes study published in February 2013 highlights how different ocean circulation was when the planet was warmer and carbon dioxide levels were high.

BY ZHONGSHI ZHANG

Ancient warm periods offer useful insights into potential future warming and its impacts. The mid-Pliocene, ~3 million years ago, was a relatively recent period of global warmth that is often considered as an analog for our future.

During this warm period, unusually warm surface conditions existed in the North Atlantic, which has often been simply explained by the intensification of the existing pattern of ocean circulation. However, reproducing these changes with climate models has eluded researchers for more than a decade—suggesting that there was something wrong either with the long-standing explanation or with the models used to predict the behavior of warmer oceans.

An alternative pattern of warm ocean circulation

Zhang, Nisancioglu and Ninnemann re-evaluated the existing observations and used the Norwegian Earth System model (NorESM) to carry out simulations to better understand ocean circulation during the warm mid-Pliocene.

They illustrated that the largest changes occurred in the deep Southern Ocean, but not in the North Atlantic, indicating that the existing explanation was not adequate.

The data and simulations pointed toward an altogether different pattern of ocean circulation, with Antarctic waters playing a stronger role due to faster renewal of the deeper water masses in the Southern Ocean during the mid-Pliocene. This alternative explanation provided a solution to the long-standing discrepancy between reconstructions of ocean circulation and available model simulations.

North Atlantic warming

The team also addressed the unusual warmth in the North Atlantic during the warm mid-Pliocene. The observed high-latitude warmth was shown not to require the intensification of today's ocean circulation and the transport of ocean heat to the north—rather it was a direct response to changes in insolation and atmospheric carbon dioxide levels at the time. The study highlights just how differently ocean circulation was when the planet was warmer and carbon dioxide levels were high.

Zhang, Z., Nisancioglu, K. and Ninnemann, U. (2013): Increased ventilation of Antarctic deep water during the warm mid-Pliocene. *Nature Communications*, 4, 1499, doi: 10.1038/ncomms2521.

The Atlantic reaches into the North

Two new research syntheses show how the northern latitudes are connected to fluctuations in Atlantic Ocean temperature.

BY **MARTIN MILES & KEN DRINKWATER**

Several Bjerknes scientists have together published two synthesis papers on how the Atlantic Multidecadal Oscillation (AMO), a natural fluctuation in ocean temperatures in the North Atlantic area usually delimited from 0–60°N, reaches into the subarctic and arctic realm.

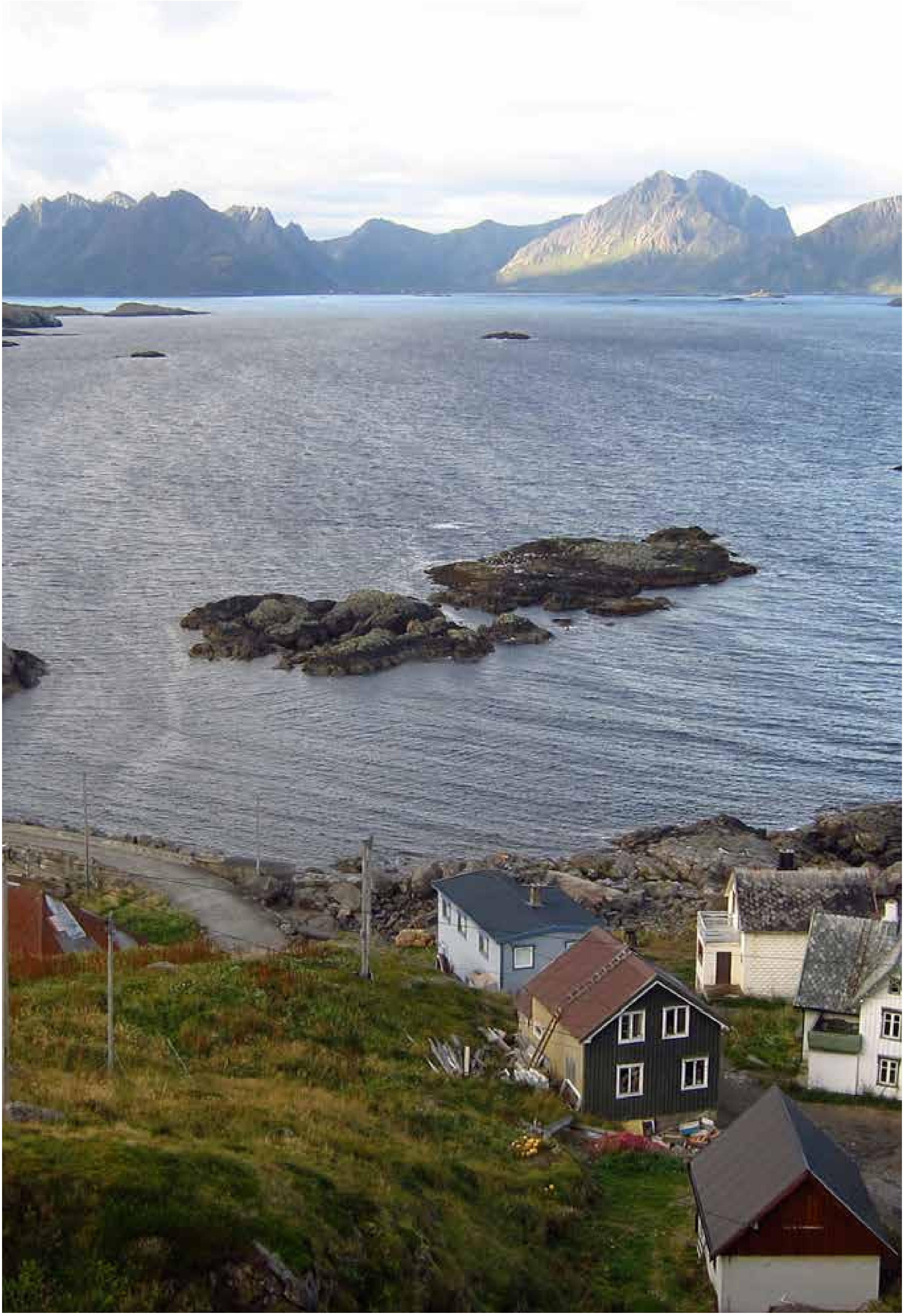
In a paper in the Journal of Marine Systems, Ken Drinkwater and others describe how the AMO is apparent in many aspects in marine regions around and beyond 60°N. Observations of air and sea temperatures over the past 100–150 years reveal cool and warm periods similar to the variability in the AMO index where a positive (negative) AMO index represents warm (cold) periods. Observations of biological impacts of the multidecadal variability in the northern regions include a general increase in plankton and fish productivity, as well as expansion of the species distributions northward, in conjunction with the AMO warm periods, and the opposite during AMO cold periods. The observed northward shifts may be an analog for the anticipated future warming.

In a paper in Geophysical Research Letters, Martin Miles and others focus on sea ice. The authors compiled and analysed historical observations extending back 100–400 years, supplemented with longer paleo reconstructions. They found a persistent multidecadal signal that is most pronounced in the Greenland Sea. In the most recent century, co-variability was found between sea ice and the AMO, and a similar relationship through previous centuries is evident from paleo data. The authors have thus provided strong observational evidence to support modelling studies suggesting that arctic sea ice is linked to the AMO. These results have implications for understanding natural variability and interpreting the recent losses in sea ice. However, the recent reductions in sea ice are not merely the latest in a sequence of natural AMO-related fluctuations, but rather the first one to be superposed upon an anthropogenic warming background that is emerging strongly in the Arctic.

Drinkwater, K., Miles, M. W., Medhaug, I., Otterå, O. H., Kristiansen, T., Sundby, S. and Gao, Y. (2013): The Atlantic Multidecadal Oscillation: its manifestations and impacts with special emphasis on the region north of 60°N. *Journal of Marine Systems*, in press, doi:10.1016/j.jmarsys.2013.11.001.

Miles, M. W., Divine, D. V., Furevik, T., Jansen, E., Moros, M. and Ogilvie, A. E. J. (2014): A signal of persistent Atlantic multidecadal variability in Arctic sea ice. *Geophysical Research Letters*, 41, doi:10.1002/2013GL058084.

↑ Swirling sea ice (white) and a phytoplankton bloom (aqua/green) near Iceland, 2012. Credit: Jeff Schmaltz, MODIS Land Rapid Response Team, NASA GSFC.



➊ Nyksund, Vesterålen. PHOTO: KERIM NISANCIOGLU

SKD CENTRE FOR CLIMATE DYNAMICS AT THE BJERKNES CENTRE

The carbon cycle and the marine ecosystem


LEADERS, **ARE OLSEN & JERRY TJIPUTRA**

As we progress through the Anthropocene, the results of human activities affect multiple processes throughout the Earth System. Warming, ocean acidification, circulation change, and changes in the atmospheric CO2 concentration in itself will enforce changes in the coupled marine and terrestrial cycles of carbon, nutrients and oxygen and transform structure and behaviour of ecosystems. BIOFEEDBACK seeks to quantify these changes and how they will feedback on the atmospheric greenhouse gas concentrations, modifying future climate development.

Observations are key to BIOFEEDBACK. They are used to inform and validate models to assess future climate and impact. Field work in 2013 included a cruise across the Greenland Sea to collect carbon system and ancillary data over the entire water column, as well as the maintenance of the autonomous instrument that measures surface seawater CO2 partial pressure on board the ship of opportunity NUKA Arctica, which crosses the North Atlantic between Denmark and Greenland on a biweekly schedule. These data will aid in determining the mechanism of anthropogenic carbon uptake as well as ventilation timescales.

BIOFEEDBACK contributes to the Surface Ocean CO2 Atlas (SOCAT) not only with data but also in terms of coordination and data management. Version 2 of SOCAT, containing more than 10 million pCO2 observations over the global oceans was released this year (Bakker et al., 2013). SOCAT and results of our global coupled model were used in the latest Global Carbon Budget (Le Quere et al., 2013) to show that CO2 emissions continued to grow in 2012, reaching 9.7 Gt C. This is slightly above the most pessimistic scenario from the IPCC 5th Assessment Report. Fortunately the ocean and land carbon sinks continue to operate, and removed CO2 corresponding to 28 and 23% of the emissions from the atmosphere.

Development and validation of the land and ocean carbon cycle components of the Norwegian Earth System model (NorESM) has been an important achievement of BIOFEEDBACK this year (Tjiputra et al., 2013). Being fully coupled, it allows for climate–carbon cycle interaction and contributed with a set of model experiments to the CMIP5 and the IPCC-AR5. Prompt delivery of NorESM simulations has led to participation in numerous intercomparison studies, where future changes in land and ocean carbon storage and the implications of anthropogenic emissions on future climate were assessed (e.g., Jones et al., 2013).

The climate feedback strength as a result of carbon cycle coupling in NorESM and other CMIP5 models was evaluated in Arora et al. (2013). The future effect of carbon–concentration feedback is expected to be 4.5 times larger than the carbon–climate feedback (see figure). Uncertainty in the land carbon cycle, indicated by the large model spread, is higher than that from the ocean due to the diverse terrestrial biogeochemical processes implemented in CMIP5 models.

In 2014 we will concentrate on improving the biological carbon pump parameterization in NorESM model, and use our global data sets to ground truth by determining the rate at which CO2 is released from decaying organic materials within the global oceans.

SKD RESEARCH PROJECT

Biogeochemical feedback in the climate system-from processes to large-scale effects - BIOFEEDBACK

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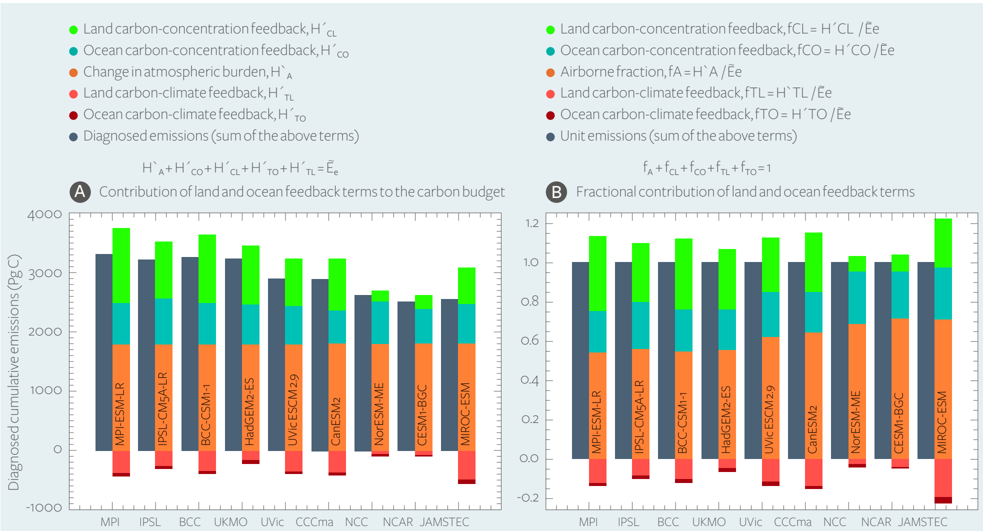
Arora, V. K. et al. (2013): Carbon–concentration and carbon–climate feedbacks in CMIP5 Earth system models. *Journal of Climate*, 26, 5289–5314.
Bakker, D. C. E. et al. (2013): An update to the Surface Ocean CO2 Atlas (SOCAT version 2). *Earth System Science Data Discussions*, 6, 465–512.
Jones, C. et al. (2013): 21st century compatible CO2 emissions and airborne fraction simulated by CMIP5 Earth System models under 4 Representative Concentration Pathways. *Journal of Climate*, 26, 4398–4413.
Le Quéré, C. et al (2013): Global Carbon Budget 2013. *Earth System Science Data Discussions*, 6, 689–760.
Tjiputra, J. F., et al. (2013): Evaluation of the carbon cycle components in the Norwegian Earth System Model (NorESM). *Geoscientific Model Development*, 6, 301–325.



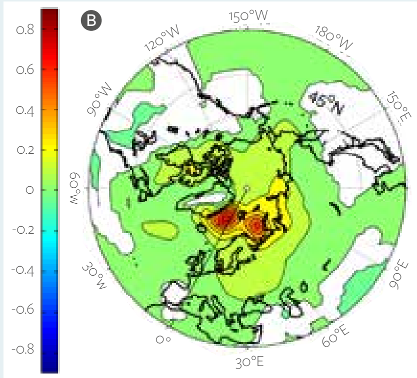
↓ A Absolute and B fractional contributions of land and ocean carbon-concentration and carbon-climate feedbacks to the atmospheric carbon budget, adopted from Arora et al. (2013).

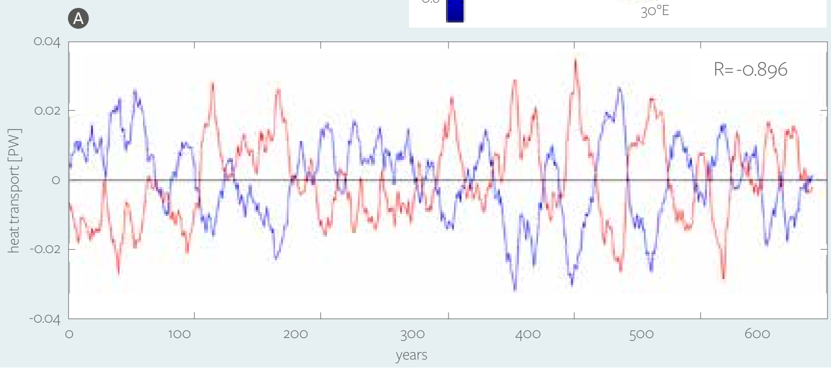
Climate sensitivity and thresholds


LEADERS, **CAMILLE LI & BJØRG RISEBROBAKKEN**

Bjerknes Compensation. (A) Heat transport in the atmosphere (blue) and Atlantic Ocean (red) for a 600-year control run of the Bergen Climate Model.

(B) Regression of simulated annual mean surface air temperature onto the atmospheric heat transport (units of K per standard deviation of heat transport time series).





Warm climates have dominated the past 65 million years of Earth history. Understanding why these past warm climates existed is critical for understanding the consequences of current and future global warming. DYNAWARM investigates how warm conditions on Earth are created and maintained by combining reconstructions of past warm climates, global model simulations of past and future warming, and studies of the physical processes contributing to polar warmth to answer questions such as:

Heat transport to high latitudes

In 1964, Jacob Bjerknes proposed that fluctuations in heat transported around the climate system by the ocean should be approximately balanced, or compensated for, by fluctuations in heat transported by the atmosphere. This so-called "Bjerknes Compensation" has been found in the control run of the Bergen Climate Model, with fluctuations in oceanic and atmospheric transport that are highly correlated on decadal timescales. The spatial signature of these fluctuations in surface air temperature has a dipole structure for the Northern Hemisphere, highlighting regions in which surface climate is strongly influenced by heat transports as well as ocean–atmosphere interactions. Critical regions are the Barents, Kara, and Nordic Seas, where the marginal sea ice allows for extremely strong fluxes between the ocean and atmosphere.

Pliocene

Of the numerous warm climate periods in the geologic record, the Pliocene (5.3–2.6 million years ago) is a particular focus because it represents an equilibrium analogue for the present climate (CO_2 concentrations similar to those expected at the end of this century and global mean temperatures 3°C warmer than today). Previously, the Nordic Seas were thought to be over 6°C warmer than today. New records suggest that Pliocene sea-surface temperatures were no more than 2–3°C warmer than present interglacial temperatures, but with an altered pattern of ocean circulation despite the similarities in continental configuration and radiative forcing.

Late-glacial and Holocene

The onset of the Bølling–Allerød interstadial in the late-glacial and the onset of the Holocene represent two major warming events in the last 15,000 years. Terrestrial biotic responses to these warmings are a combination of population expansion, migration, and niche shifts, and a few local extinctions. Responses to the Younger Dryas cooling and the late-Holocene cooling after the Holocene Thermal Maximum are primarily local or regional extinctions. Regional climate-model simulations for Europe at 6000 and 200 BP indicate increasing climatic sensitivity to anthropogenic deforestation. Challenges are thus to disentangle biotic responses to late-Holocene climatic changes per se, to direct human activity, and to a combination of drivers.

Cryosphere

Potential thresholds in the cryosphere (sea ice and ice sheets) are a concern in today's warming world. One question is how sea ice will be affected by projected increases in river runoff to the Arctic Ocean. Modelling experiments reveal a complicated oceanic response. More runoff strengthens the protective surface layer and stabilizes the upper ocean; at the same time, the surface layer thins, allowing the underlying warm Atlantic water to move up towards the base of the ice. Another question is how the Greenland ice sheet will respond to a warmer climate. The most recent period with high-latitude temperatures warmer than today is the last interglacial (~130–115 thousand years ago). Under last interglacial climate conditions, ice-sheet model simulations show Greenland melting. This melting occurs mostly on the margins, while the central height of the ice sheet decreases by only a few hundred metres. The total amount of melting depends largely on the initial size of the ice sheet and reaches ~1–3 m in sea-level equivalent.

SKD RESEARCH PROJECT

Dynamics of past warm climates – DYNAWARM

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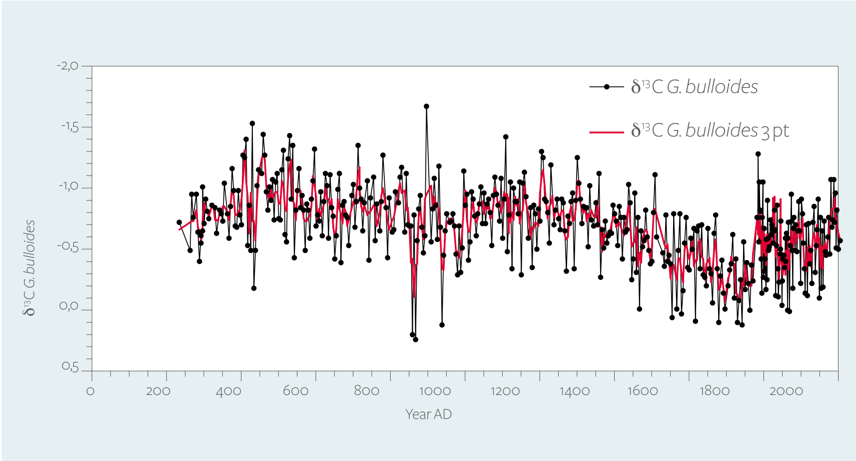
NERSC: Igor Ezau

Natural and anthropogenic climate changes

LEADER, **ODD-HELGE OTTERÅ**



Example of high-resolution (~5 years) paleo reconstructions generated by IMMUNITY. The plot shows $\delta^{13}C$ composition of G.bulloides. The amplitude of the signal is large, with a maximum in $\delta^{13}C$ associated with the Little Ice Age. Strong negative values predominate during the Medieval Warm Period.

The primary object of IMMUNITY is to integrate novel palaeoclimatic time series at unprecedented temporal resolution and instrumental data together with coupled atmosphere–ocean–sea-ice general circulation model simulations, in order to explore the long-term climate variations during the last 1500 years.

Analyses so far indicate that paleo reconstructions of ocean state variables generated by IMMUNITY deliver a temporal resolution that reflects the main decadal trends of instrumental data and thus can be used with confidence to develop a longer-term climate perspective (see figure). IMMUNITY has generated promising multiproxies for the reconstruction of key climatic features, such as deep overflows through the Iceland–Scotland ridge (Mjell et al., in prep) as well as frequency of storms and floods on land in Norway during the past millennia.

Major efforts have been devoted into a computationally efficient lower-resolution version of NorESM to make it suitable for millennial simulations and decadal prediction ensemble integrations. In this regard, the comparison of simulated and observed circulation of the North Atlantic gyre has given promising results.

Progress also has been made in elucidating the governing mechanisms behind multi-decadal climate variability. The use of virtual drifters shows that, even in a coarse climate model, it is unusual for large volumes of warm surface water to be transported by the Gulf Stream into the Nordic Seas and Arctic (Medhaug and Czaja, in prep). Instead, observations and modelling agree that warm surface waters mostly recirculate in a loop and rarely reach high latitudes. In another investigation, the probability of having negative regional and global temperature trends for a control climate, historical observations and simulations, and for future scenarios using 17 models from CMIP5, has been analysed (Medhaug and Drange, in prep.). This analysis shows that the hiatus we have experienced the last decade or two is not uncommon even though we are experiencing a general warming of the global temperatures.

Potential mechanisms for decadal variability in the Pacific and East Asian summer monsoon have also been addressed during the past year. The role of anthropogenic forcing in shaping the weakened East Asian summer monsoon and associated anomalous precipitation in eastern China over the late 20th century (Wang et al., 2013) is highlighted. Finally, model output from the Bergen Climate Model and observations suggest that intensified solar radiation in combination with a lull in volcanic activity during the 1920s–1950s can explain much of the early 20th century Arctic warming (Suo et al., 2013).

SKD RESEARCH PROJECT

Integrated model–data approach for understanding multi-decadal natural climate variability – IMMUNITY

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NERSC: Yongqi Gao, Helene Langehaug

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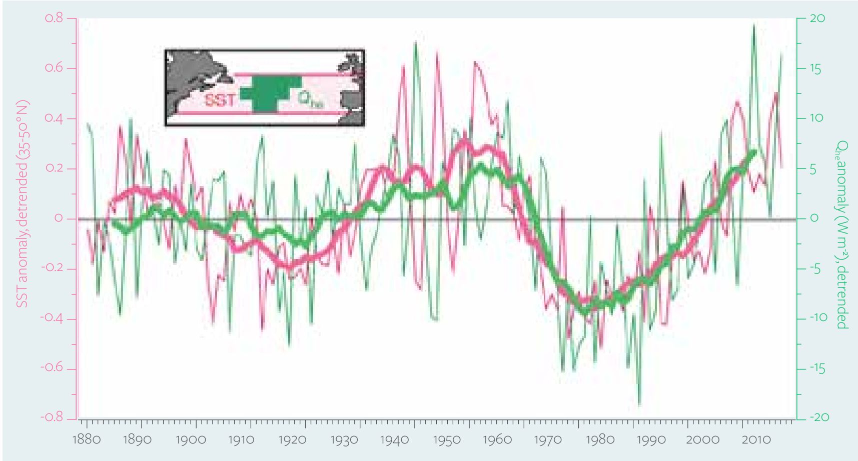
Medhaug, I. and Czaja, A. Surface exchange between the subpolar and subtropical North Atlantic using virtual drifters, *in prep*.
Medhaug, I. and Drange, H. Negative global and regional temperature trends in a warming climate, *in prep*.
Mjell, T. L., Langehaug, H. R., Otterå, O. H., Eldevik, T., Ninnemann, U. and Kleiven, H. F. Reconstructing ocean circulation and climate based on the Gardar drift, *in prep*.
Suo, L., Otterå, O. H., Bentsen, M., Gao, Y. and Johannessen, O. M. (2013): External forcing of the early 20th century Arctic warming. *Tellus A*, 65, 20578.
Wang, T., Wang, H., Otterå, O. H., Gao, Y., Suo, L., Furevik, T. and Yu, L. (2013): Anthropogenic forcing of shift in precipitation in Eastern China in late 1970s. *Atmos. Chem. Phys.*, 13, 12433-12450, doi:10.5194/acp-13-12433-2013.

Process understanding and uncertainties

LEADER, **TOR ELDEVIK**



Sea-surface temperature (red) and the associated heat flux from the ocean to the atmosphere (green) averaged over the extra-tropical North Atlantic. Thick curves show the 11-year moving average. Two important inferences can be made from this figure, both supporting a predictable climate rooted in the ocean: 1) the ocean warms the atmosphere on decadal time scales, and 2) the variance on decadal time scales is of similar magnitude to the interannual (reproduced from Gulev et al., 2013).

Will Norway experience cold and dry winters in the next few years? Will the Northern Sea Route become more accessible? Climate prediction models, principally like those for weather forecasting, are under development to answer such questions of large societal importance, or, more precisely, to provide a confident range and probability of possible outcomes.

Dynamical seasonal-to-decadal climate prediction is an emerging research field. Recent progress is documented in the IPCC WG1 Fifth Assessment Report (AR5); it is in general still unknown to what extent climate is predictable on interannual to decadal timescales – both from a theoretical and a practical perspective. In PRACTICE, the Bjerknes Centre has invested to make climate prediction a strategic priority. The Norwegian Climate Prediction Model (NorCPM) has accordingly been realized and tested in an idealized framework (Counillon et al., 2014; see also page 13).

With a first prototype of NorCPM in place, the Bjerknes Centre is now engaging more actively in the international research effort to resolve this scientific question of foremost societal importance. PRACTICE has in parallel kept a strong focus on assessing potential predictability from confronting possible mechanisms with the observational record. Key cause-and-effect relations have been indicated, e.g., for North Atlantic atmosphere–ocean heat exchange (Gulev et al., 2013, see figure and page 14), and for the strength and structure of the Gulf Stream's extension toward and into the Arctic (Eldevik and Nilsen, 2013; Lien et al., 2013, see also pages 12 and 13). Such identified relations will increasingly be converted into corresponding frameworks for model evaluation (Sandø et al., 2014).

The PRACTICE team dedicated much of 2013 to consolidating and further increasing the resources for climate prediction as a core activity at the Bjerknes Centre. Four projects were funded as a result, with EPOCASA (RCN) and PREFACE (EU) for further testing and development of the NorCPM-system in a realistic framework, and GREENICE (Nord-Forsk) and NORTH (RCN) more dedicated to mechanisms and associated frameworks for model evaluation. Through the national and international consortiums thus established, links are now formalized with the main EU projects on climate prediction (NACLIM and SPECS).

An emerging priority for PRACTICE is to develop – in parallel with the ongoing research and model developments on predictability – tailored prediction output fit for decision makers, resource management, businesses, and the general public. PRACTICE has thus actively engaged in a recently submitted proposal for a "Centre for Research-based Innovation" in Bergen on the topic, and in a national research plan commissioned by the Ministry of Education and Research for a holistic assessment of the ecosystem of the Barents Sea (Eldevik et al., 2013). The aspect of predictability and regional impacts of climate change will be advocated as a priority for the next round of SKD strategic projects.

SKD RESEARCH PROJECT

Predictability of Arctic/North Atlantic climate
– PRACTICE

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NERSC: Laurent Bertino, François Counillon, Jan Even Ø. Nilsen

IMR: Kjell Arne Mork, Anne Britt Sandø, Øystein Skagseth

Counillon, F., Bethke, I., Keenlyside, N., Bentsen, M., Bertino, L. and Zheng, F. (2014). Seasonal-to-decadal predictions with the Ensemble Kalman Filter and the Norwegian Earth System Model: a twin experiment. *Tellus A*, in press.
Eldevik, T. and Nilsen, J. E. Ø. (2013): The Arctic–Atlantic thermohaline circulation. J. *Climate*, 26, 8698–8705.
Eldevik, T., Reigstad, M., Falck, E., Gerland, S., Jentoft, S., Johnsen, G., Lindstrøm, U., Rasmussen, T. L., Rød, L. P. and Wassmann, P. F. (2014): *Arven etter Nansen*. Forskningsplan for det sentrale og nordlige Barentshavet. UiT Norges arktiske universitet, 48pp. (nansenlegacy.org)
Gulev, S. K., Latif, M., Keenlyside, N., Park, W. and Koltermann, K. P. (2013): North Atlantic Ocean control on surface heat flux at multidecadal timescales. *Nature*, 499, 464–467-
Lien, V. S., Vikebø, F. B. and Skagseth, Ø. (2013): One mechanism contributing to co-variability of the Atlantic inflow branches to the Arctic. Nat. *Commun.*, 4, doi: 10.1038/ncomms2505.
Sandø, A. B., Y. Gao, and H. R. Langehaug (2014), Poleward ocean heat transports, sea ice processes, and Arctic sea ice variability in NorESM1-M simulations, J. *Geophys. Res. Oceans*, 119, 2095–2108, doi:10.1002/2013JC009435.

Regional climate scenarios and extremes

LEADERS, **ANNE-BRITT SANDØ & STEFAN SOBOLOWSKI**

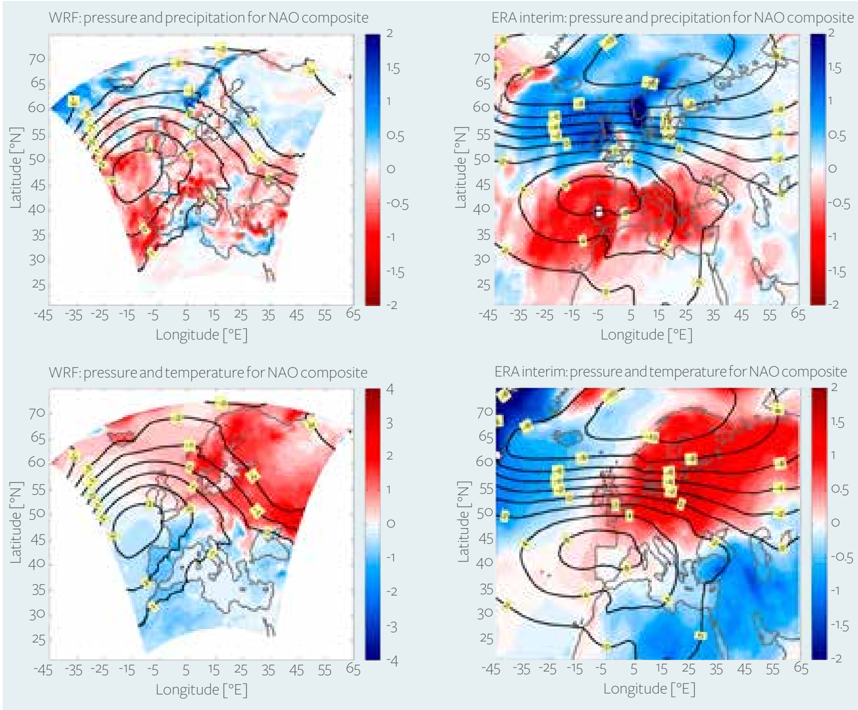

Figure caption: NAO composite (NAO+ minus NAO–) for precipitation (top row) and temperature (bottom row) in the WRF-hindcast (left column) and ERA-interim (right column), composited pressure contours shown in black.

In 2013 REGSCEN continued building and testing the COAWST modelling system, which now employs two-way coupling between the ROMS and the WRF models for the simulation of a well-observed polar-low case. The coupled simulation captures the essential features of the polar low despite biases, particularly in the surface fluxes. The differences between the uncoupled and the coupled simulations do not seem to be significant at the synoptic scale. However, the behaviour of the ocean model appears to be unrealistic, most likely because of the vertical mixing near steep bathymetry. Efforts are being made to improve the ROMS simulation so that the air–sea interactions during the growth of the polar low can be studied and the results published. This is also necessary in order to use the modelling system in climate experiments where small errors can compound over time to become prohibitively large. The next step is to employ the COAWST system with interactive sea ice, as part of the Arctic-CORDEX research group and contribute to an ensemble of atmosphere only and fully coupled regional downscaling of the CMIP5 models over this important region. Issues related to physical mechanisms linking the observed Arctic amplification to larger scale circulation, regional impacts of climate change, high-impact weather along the ice edge, and processes in the marginal ice zone are just a few of the scientific themes to be investigated.

Downscaling NorESM under the RCP4.5 and RCP8.5 scenarios continued in 2013 over multiple regions with a focus on Europe. Errors in some of the diagnostic variables demanded historical and future simulations to be rerun and post-processing to strict and ever-changing CORDEX specifications remain a challenge. Currently, data are available on Norway's ESGF node. The collaborations emerging from this activity continue to bear fruit and four manuscripts are in preparation on topics that include solar power potential, snow cover, extreme winds and uncertainty quantification, as well as two manuscripts in preparation on NAO variability (see figure) and moisture transport.

Global Earth System Model projections for the end of the 21st century show generally a decrease of primary production, which is attributed to an increasing seasonal and permanent stratification caused by future warming. Regional Earth System model projections, which consider the full range of climatic induced changes in ocean hydrodynamics and biogeochemistry, find this first-order effect to be largely absent on the regional scale. Instead, highly heterogeneous patterns with both positive and negative changes were projected for the regional hydrodynamic, biogeochemistry and lower trophic level ecosystems, and hence higher up into the food web. These changes result from a complex interplay of competing processes such as wind forcing, stratification, local short wave radiation, oceanic nutrient conditions and terrestrial forcing. While this needs to be considered on a case-by-case basis, some general principles were identified. When there are multiple effects of different sign, these will tend to mitigate the climate-change impact, suggesting that some regional seas will generally be less vulnerable to climate-change effects than the open ocean. The findings were published in three different research papers.

SKD RESEARCH PROJECT

Regionalisation of climate scenarios – REGSCEN

INSTITUTIONS AND STAFF INVOLVED

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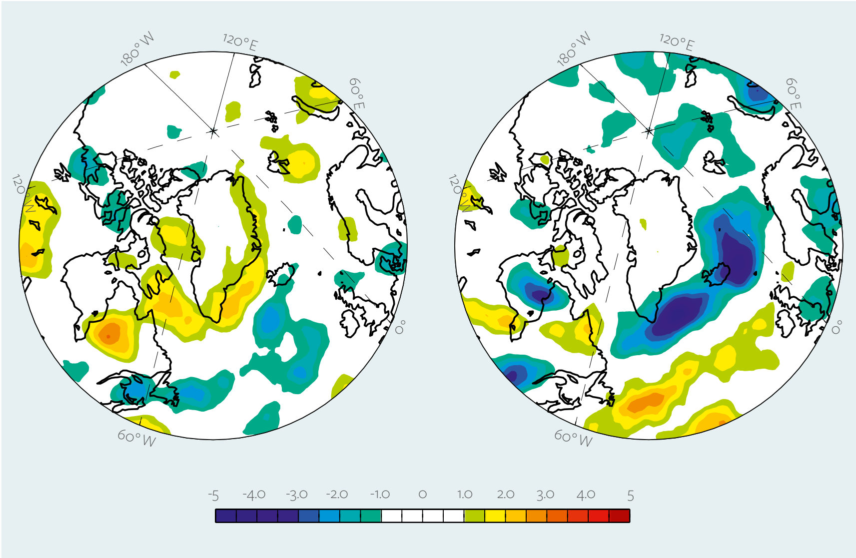
SKD CENTRE FOR CLIMATE DYNAMICS AT THE BJERKNES CENTRE

Past, present and future changes in sea level

LEADER, **JAN EVEN Ø. NILSEN**



➊ Patterns of cyclone activity during years of strong snow accumulation (left) and during years of high air temperatures (right) over the Greenland Ice Sheet. This shows that strong cyclone activity in the North Atlantic is associated with positive contributions to the mass of the ice sheet, but in a different manner depending on their tracks: When more or stronger storms travel close to Greenland (orange to green region in left panel) there is more snow, and when more or stronger storms travel further away (blue region in right panel) there is less surface melting on Greenland.

The project SEALEV is designed to understand past and present changes in the Greenland Ice Sheet (GrIS) and to project future rates of sea-level rise under climate change, for the Norwegian and other coastal regions. There is a strong focus on the processes in and over the ice sheet, and deliverance of freshwater to the ocean. With respect to regional sea-level rise, SEALEV has a strong observational basis, combining ocean density with remotely-sensed sea-surface height and gravity to assess the combined effect of mass exchange, steric changes and ocean dynamics on sea-level rise across the oceans. The geology work package quantifies past changes in sea level and ice sheets. A consistent system to improve sea-level projections in the 21st century is ensured by a strong core of modelling activity.

During 2013, SEALEV has been capitalizing on the efforts since the start of the project. Through the combination in situ hydrographical data, surface drifter data and direct current-meter measurements, together with coupled sea ice–ocean models, altimeter data and the latest GOCE-based geoid, knowledge of the circulation and sea level in the Nordic Seas and Arctic Ocean has been improved. Constraining the surface elevation of the GrIS from combined satellite altimeter measurements has been improved greatly by multi-instrumental comparisons and assessment of uncertainties. It emerges that while the lower regions have been losing mass for many years, it is only in the latter years that the ice sheet has shown an overall sinking tendency. The studies of the atmospheric impact on the GrIS show that there are two main types of cyclone activity around Greenland, having both direct and indirect impacts on the accumulation and air temperature over the ice sheet (see figure). High-resolution records of the retreat and calving rates of the Sermilik Fjord outlet glaciers since 1980 have revealed unexpectedly volatile advance-retreat behaviour of one of Greenland's largest ice-sheet outlet glaciers, which underscores the complex nature of glacier variability and its interpretation as a response to climate change. The fjord-to-ocean modelling is on-going with a fine-scale coupled model setup with ocean, atmosphere, and ice shelf modules, showing in detail how Atlantic-derived waters penetrate Sermilik Fjord towards the outlet glaciers.

Published results from ice-sheet modelling based on CMIP5 models show that GrIS contribution to global sea-level rise may be as much as 13 cm by 2100 for the RCP8.5 emission scenario.

From the DATED database the time evolution of the Eurasian Ice Sheet through the past 25–10,000 years has been reconstructed, forming a unique basis for testing of both numerical ice-sheet modelling as well as GIA-modelling.

The earth system model NorESM has been further updated for sea level studies through, among other improvements, implementation of fresh water as mass (FWAM), and preparation of the NorESM ocean component for ice-shelf interaction.

SKD RESEARCH PROJECT

Sea level change and ice sheet dynamics – SEALEV

INSTITUTIONS AND STAFF INVOLVED

NERSC: Jan Even Ø. Nielsen, Linling Chen, François Counillon, Kirill Khvorostovsky, Johnny A. Johannessen, O.M. Johannessen, Victoria Miles, Qing Yan

UIB: Helge Drange, Ilker Fer, Jan Mangerud, Atle Nesje, Kerim Nisancioglu, John Inge Svendsen, Kristian Vasskog

Uni Research: Mats Bentsen, Martin Miles

IMR: Lars Asplin, Mari Myksvoll

SOFT-SPOKEN, BUT WITH A BURNING COMMITMENT – Climate change is a message that must be shared with others, and people have every reason to be informed about it, says climate researcher Eystein Jansen, who recently resigned as director of the Bjerknes Centre.

The Climate Diplomat

Although he dislikes being in the limelight, Eystein Jansen succeeds in putting climate research in Bergen on the world map.

BY **ELIN STENSVAND**, PHOTO **EIVIND SENNESET**
THIS ARTICLE IS A TRANSLATION AND A SHORT VERSION OF AN INTERVIEW PUBLISHED IN THE UNIVERSITY OF BERGEN'S RESEARCH AND EDUCATION MAGAZINE, HUBRO

It is January 2014, and Eystein Jansen's everyday life is changing. After serving for 13 years, he has resigned as director of the Bjerknes Centre for Climate Research, a centre he has headed since its foundation in 2000. He is resigning on his own volition – at the peak of his career, many will say.

Because the west wing of the Geophysical Institute is under renovation, Jansen has been banished to a smaller, more cramped group room for the interview. He sits here now, amongst cartons and furniture items, and can do nothing about it. He is drinking green tea. Lots of green tea. His voice is gentle, but the words that come out are well chosen and determined.

You are resigning as director of the Bjerknes Centre after 13 years, so that must mean that you are not superstitious?

– No, I am neither religious nor superstitious, Jansen smiles. It's purely by chance that the number of years is 13, but this was a very suitable time to resign. We have undergone a process to develop a better defined organization, and so it was a suitable time for someone else to have a go. In addition, we have had a very good year, including the financing of many new projects. It's not fitting to leave if there is a crisis and others have to clean up. It's much better to hand over something that is working well.

Youthful enthusiasm

There was nothing in the cards that said he would become a climate researcher. As a young man, Eystein Jansen considered studying medicine. However, his curiosity about why the landscape looks the way it does, combined with a fundamental joy in the outdoors led him to study geology.

As a postgraduate, he had the opportunity to conduct advanced chemical analyses in Germany; this was part of a wish on the part of the research environment in Bergen to build a laboratory. No one else had the necessary experience.

– My job was to participate in the drafting of an application that would be better than the one

submitted by the University of Oslo, so that we could get the laboratory built in Bergen. When we won the competition, there was a vacant position at the laboratory, and I was hired.

Pretentious visionary

His new position opened the path towards a career in palaeoclimate research.

– *The visions we had for the Bjerknes Centre when we started were quite pretentious,* Jansen says. – *We started up with the objective of becoming one of the first Centres of Excellence in research. When we were accredited in autumn 2002, the entire situation changed. We went from being a loose network of people who wanted to develop things to a group having a whole new set of muscles to work with.*

Jansen is characterized as a leader who is good at getting people to cooperate, and he is given much of the credit for having made the interdisciplinary collaboration between institutions a well-functioning system.

– *I think that might be one of my strengths. There have been episodes in which some of the institutions felt the Bjerknes Centre has taken up too much space in contrast to their own institutions. Myself, I think that this is a necessity that we should be more open to acknowledging.*

You are characterized as a diplomatic, gentle man, but one with a firm message. How do you reconcile those two character traits?

– *I am a shy person in nature, and I think I can get further without using sharp elbows. Particularly when it is a question of building cooperation, it is unwise to adopt a military style of leadership. My style of leadership is maybe less insistent, but I probably do have an ability to think strategically and to see possibilities in the longer term, as well as what needs to be done to realize them. But you have to get people to work with you in the same direction.*

Are you good at convincing people?

– *I am a firm believer in good, mutual conversations.*

Bergen on the world climate map

The Bjerknes Centre decided very early to produce global climate simulations in conjunction with the United Nation's climate reports. The centre's ambition was that Norway should have a model system that generated global simulations.

– *The research community in Oslo was very negative to this idea. They had tried this themselves and failed. They therefore thought that it would be biting off more than one could chew,* Jansen recalls.

With determined work, Jansen and his colleagues forged an environment resulting in several Bergen researchers' having key roles in global climate research today.

– *By the fourth report, there were only four centres in Europe that could offer global climate scenarios, and we were one of the four. The establishment of the Bjerknes Centre as a heavy international research institute has been very important.*

In September 2013, the UN's climate panel, IPCC, presented the first sub-report in the fifth report on climate. Jansen was one of the key researchers responsible for this. In 2007 he was the only Norwegian researcher to participate in the final discussions on the UN's fourth report on the climate.

– *The most exciting thing about being involved with this is that you get an overview of all the climate research available, and you also get total immersion in your own scientific field,* Jansen says.

Do you sometimes lose sleep and worry about climate in the future?

– *It's not quite that bad yet. But there is every reason to be worried. The knowledge we have now is not pleasant and is therefore important to communicate to the public. So we spend very much time, in all kinds of forums, giving lectures about these things. By the time we presented the report, I had given more than thirty lectures, and I am looking at a minimum of one per week from now on.*

A new everyday life

At the turn of the year, Jansen embarked on a new everyday life. He will still work at the Bjerknes Centre, but now with the title of researcher and advisor. He looks forward to having more time for his own research.

– *I have spent a lot of time and effort on making provisions for others. Among other things, I have missed being able to implement my own ideas from the ground up rather than delegate everything to others,* he says.

Before Christmas it was announced that the Bjerknes Centre will receive between 50 and 60 million Norwegian kroner from the European Research council (ERC) to investigate what will happen with the Greenland ice sheet if the ocean ice in the Norwegian Sea and the Arctic Ocean disappears. Of a total of 450 project applications from all disciplines, only 13 got through the eye of the needle.

– *Getting this project approved was incredibly rewarding. Many people thought it was pointless to apply, but we thought that this was an important issue, one that could only be solved if we had large financial resources available. With my background, it was especially nice to get this project grant now, towards the end of my career, and to prove that palaeoclimate research in Bergen is world-class.*

FACTS / Eystein Jansen

- Professor in Palaeoclimatology at Department of Earth Science.
- Born 28 February 1953 in Bergen.
- Research Director at the Bjerknes Centre for Climate Research from 2000 to 2013.
- Doctorate in marine geology from the University of Bergen in 1984.
- Coordinating first author of chapter 6, Palaeoclimate, for the IPCC's 4th report. Assessment report published in 2007 and first author for Sub-report 1: Climate Change - the Physical Science Basis, IPCC 5 Assessment report.
- Member of the Norwegian Academy of Science and Academia Europaea.
- Has published more than 120 scientific articles, several of which appeared in the respected periodical Nature.

Climate issues back on the media's agenda during the launch of the IPCC-report

The launch of the Fifth Assessment Report of the IPCC in September this year constituted an important moment in the continuous media discourse on climate change.

BY **JILL JOHANNESSEN**

In total, the Bjerknes Centre was referred to in roughly 600 articles (592 until Dec. 11) in the news media and public web-based sources during 2013. This number includes articles online and paper, but excludes news items in broadcast media. While the media year had a slow start for the Bjerknes Centre, the launch of the Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) pumped up the media coverage. During ten days, from September 20–29, the Bjerknes Centre was involved in more than 130 news items. The bulk of these articles were news items linked to the IPCC launch and published on September 27, which was the day of the launch of the report. The media coverage involving the Bjerknes Centre was also stronger in the months after the event than the rest of the year.

Compared to the IPCC launch in 2007, the media coverage involving the Bjerknes Centre in the IPCC launch in 2013 was similar in numbers, but with more attention in the lead-up to the event. This could be due to a general media trend, but also due to deliberate media work ahead of the event in which we wanted to spread out the attention and to trigger attention ahead of the launch.

The human footprint changing the earth

On the side of the Bjerknes communication strategy, we tried to push for different scientific angles (how climate change impacts different elements of the climate system) ahead of the IPCC-launch, which was reflected in the news output. On the day of the launch, we emphasised humanity's footprint on the climate system – which now can be identified in more and more parts of the system – in both the Bjerknes press release and IPCC lead author Eystein Jansen's presentation under the national press conference. The message had moral and political undertones. It was linked to the possibility of reaching the two-degree target and the need for transforming to a renewable energy society, as well as our moral responsibility to future generations' well-being. These messages were echoed in several the major media houses, e.g., Aftenposten, Bergens Tidende (see example below), and NRK as well as local papers such as Haugesunds Avis, or more specialist media such as Yr.no (all published on September 27th).

The IPCC launch & outreach materials

The Bjerknes Centre joined forces with CICERO Center for Climate and Environmental Research, the Norwegian Polar Institute, and the

- Vi har fotavtrykk i hele klimasystemet

FNs nye klimarapport: - Vi ser nå tydelige fotavtrykk av menneskehetens utslipp i store de-

ATLE ANDERSSON, KAY-ÅGE STRØM-GRØTAN

Publisert: 27 sep. 2013 11:15 Oppdatert: 27 sep. 2013 12:16

Det sa professor Eystein Jansen, direktør ved Bjerknessenteret, da hovedrapporten til FNs klimapanel ble lagt frem i formidl
Cecilie Mauritzen, direktør ved Senter for klimaforskning (CICERO), sammenfattet innholdet slik:
- Det er like sikkert at kloden varmes opp som at solen kommer til å stå opp i morgen tidlig.

Facsimile, Bergens Tidende 27. sept. 2013.

Norwegian Environment Agency in launching IPCC's first report on the national scene. The collaboration held a press conference in Oslo in parallel with the international launch in Stockholm, as well as breakfast meetings in Oslo, Bergen and Tromsø prior to the launch. In addition, the collaboration produced outreach material in Norwegian that summarized the most important results. The Bjerknes Centre was responsible for two fact sheets concerned with climate change in Norway, present and future scenarios, which involved a positive communal effort from many scientists of the Bjerknes Centre. The fact sheets have been an important contribution and distributed to a range of different actors, e.g., politicians, journalists, and schools.

➊ The Board was present to celebrate the Christie prize. From left: Eystein Jansen, Tore Furevik, Tore Nepstad (IMR), Stein Sandven (NERSC), Dag Rune Olsen (UiB) and Arne Svindland (Uni Research).
PHOTO: PAUL S. AMUNDSEN/UIB

➊ UiB rector, Dag Rune Olsen, from the board of the Bjerknes Centre and director of CICERO, Cecilie Mauritzen, during the award ceremony.
PHOTO: TOVE HOFSTAD, VENSTRE

Bjerknes Centre receives the Christie Prize

"This is a great acknowledgement of what we have accomplished, both in research and outreach", Eystein Jansen said when the Bjerknes Centre was awarded the Christie Prize by the University of Bergen at the Christie Conference on 25 April 2013.

The annual prize of NOK 250,000 is awarded to a person, a group of persons, a company or an institution that contributes to better cooperation between the University of Bergen and the community of western Norway at large.

Prof. Jansen was happy and proud to receive the prize, and states:

"Communication with people outside the scientific community has always been important for the scientists at the Bjerknes Centre. Our policy has been to say yes to inquiries from the media. We work with themes that are relevant for many, and needs to be communicated."

The Bjerknes Centre and CICERO share Venstre's Environmental Prize 2013

Venstre is Norway's social liberal party, and decided to share their environmental prize 2013 between the two large climate research centres in Norway. While the Bjerknes Centre takes care of the natural science research on climate, CICERO (Center for International Climate and Environmental Research – Oslo) conducts research on climate change and climate policy.

According to Venstre and the jury, *"future climate change is the largest challenge for the coming generation. Both the BCCR and CICERO have been outstanding in their outreach on these important topics"*. The UiB rector Dag Rune Olsen received the prize in Oslo in October on behalf of the Bjerknes Centre, together with Cecilie Mauritzen, former director of CICERO.

➊ Bakke and his crew picked up a block of ice from the Folgefonna glacier and brought it back to Bergen.
PHOTO: JOSTEIN BAKKE

➊ Discussing the Finse blues. There is often a blue sky above the Hardangerjøkulen.
PHOTO: KERIM NISANCIOGLU

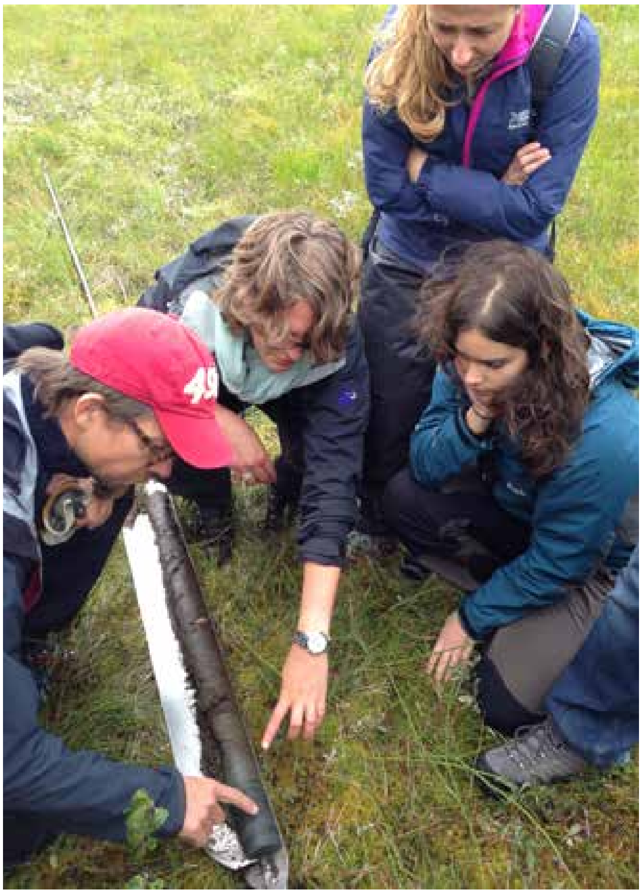
Ancient air bubbles trapped in ice from the Folgefonna glacier

During the annual Norwegian Science Week several Bjerknes researchers participated in the program, in debates and talks. At the science fair, "Bubbles in ice" was the name of the stand by Professor Jostein Bakke at the Department of Earth Sciences, UiB. Air bubbles captured in the glacier contain traces of the climate thousands of years ago. Bakke and his crew picked up a block of ice from the Folgefonna glacier and brought it back to Bergen. In addition of being a research tool, the ice was used on a stand at the science fair. Visitors, mostly young pupils and families, joined in on experiences where they could examine the air bubbles in microscope, and see the effect on sea level of melting ice on land versus ice melting on sea. In addition, several young researchers informed about different research projects related to glaciers and how they can be used in paleoclimatic research. Also popular was the possibility to dress up as a scientist working on the glacier with crampons, harness, ice axe and helmet.

Geoscience tracks on app

During five days in September, Master's and PhD students from Bergen gathered at Finse for a five-day course on science communication and outreach. The course was organized by ResClim and the Bjerknes Centre in collaboration with the Centre for Science Education at UiB and included lectures from the Department of Earth Sciences, the Geophysical Institute, the Department of Physics and Technology, the Science Museum in Bergen (VilVite) as well as a local high-school teacher. One task during the course was to further develop the "Turspor" concept developed by associate professor Kerim Hestnes Nisancioglu. This is a project taking science education from the classroom and out into the field, teaching geoscience to high-school students and the general public. "Turspor" includes documented hiking routes at Dovre and Finse with geo-referenced points of interest describing the local geology, weather and climate. During the 2013 science communication course at Finse, the students were challenged to develop new points of interest relating to the local geology, weather and climate and in the coming year the concept will be expanded to the mountain areas of Rondane and Jotunheimen. Turspor is a collaboration between UiB, the Bjerknes Centre, the national public broadcasting company (NRK), and the national trekking association (DNT), and is made available through the website UT.no, as well as their associated app.

The spectacular landscape of Vesterålen made the scene for the ACDC summerschool 2013. Photos from field trips and the Nyksund village.
ALL PHOTOS: DAVID BATTISTI



Tasting a sediment core. Fresh peat to taste and smell for teachers and pupils.
PHOTO: KERIM NISANCIOGLU

Spectacular Summer School in Vesterålen

There was a record 131 applicants for the 27 places in the Advanced Climate Dynamics Course 2013. The lucky 27 advanced PhD students gathered with 12 teachers in Nyksund, Vesterålen for the fifth ACDC Summer School in late August. In spectacular scenery, the participants attended a summer school with main focus on the dynamics of the last deglaciation using models and proxy data.

In addition to fundamental lectures on core topics, the participants joined two days with field trips. The participants at the summer school also arranged an "open day" for local schools, where they were introduced to climate, geology and meteorology in their own home landscape. The teachers and pupils even smelled and tasted peat from a fresh sediment core.

Near Nyksund, the landscape holds a remarkably rich geomorphological record with a wide variety of different landforms formed under contrasting climate conditions. These include empty glacier cirques, relict rock glaciers, avalanche deposits, marine terraces, weathered regolith surfaces, alpine peaks, and this is one of the few places in Norway were you can find remains of what appear to be land-based Last Glacial Maximum (LGM) moraines.

ClimateSnackers dissecting a text the Geophysical Institute.
From left: Hella Wittmeier, Anne Morée, Ragna Breines and Mathew Reeve.
PHOTO: GUDRUN SYLTE

CLIMATESNACK

Becoming a better scientific writer

Climate Snack, "the writing skills improvement project for early career scientist", was officially launched by Mathew Stiller-Reeve at the Bjerknes Getaway in January 2013. His idea was to build a community "with aspirations of improving the scientific writing skills of the young and early career climate scientists who take the leap and become authors". ClimateSnack aims to provide ready-made platform to offer climate scientists a way to practice and improve their writing skills.

Mathew had clearly addressed a need among young scientists, as a year later he could sum up a successful year. Starting up with the Norwegian name Klimasnakk, the English name ClimateSnack is now most widely used. New writing groups keep popping up at universities around the world. As of March 2014 there were already several groups in Norway, UK, Sweden and USA. Several more groups are starting in the UK, USA, Germany, Switzerland and hopefully also in Tanzania, Uganda and South Sudan.

Hella Wittmeier and Wally Broecker. Broecker's career started in the late 1950s at the Lamont-Doherty Earth Observatory of Columbia University in New York, and here he still keeps busy today, as Newberry Professor of Earth and Environmental Sciences.
PHOTO: GISELA WINCKLER

Captain Climate – Talking to Wally Broecker

When visiting the Lamont-Doherty Earth Observatory of Columbia University in New York, Hella Wittmeier made an interview with the legendary climate researcher, Professor Wally Broecker. This interview is a short version; the full-length version can be found in two parts at ClimateSnack.com

BY **HELLA WITTMEIER**, BASED ON TWO CLIMATESNACKS

Wally Broecker is a climate researcher who has had so much impact in his field that he is considered one of the most important figures in ongoing climate research. He is the climate science pioneer who invented the very expression global warming, who discovered the ocean conveyor belt and revolutionized our understanding of the ocean's role in the world's climate. He is the research innovator who has done ground-breaking research in the carbon cycle, and with others invented the radiocarbon method, which is one of our most valuable tools in dating climate events back in time.

When asking Wally of the main unanswered question in climate research today, his answer comes fast and accurate. He gives me a list of issues that still puzzle him – all linked to the relation between CO_2 and ice extent. Asked about how we can answer these questions technologically and socially, Wally answers:

"Putting CO_2 into the atmosphere has been mankind's greatest geophysical experiment. We are learning that the climate system turns out to be a hell lot more complicated than we initially thought. On the time scale that this is all going to happen, we will not be able to make really good predictions. It is just too complicated. I am pushing, because fossil fuels are so cheap, and it is clear that with technology we will find even more than we found now. And right now they are cheaper than any other source of energy. I think we will have to pull CO_2 out of the atmosphere. Klaus Lackner at Columbia knows how to do it, but he can't get the money to build the prototype."

So where can this money come from? Our governments maybe? Wally talked to Jens Stoltenberg, while he was Prime Minister of Norway, one of the wealthiest oil producing countries in the world.

"I said, you know, you as a nation are ahead of everybody else, in taxing carbon and so forth, why don't you use some of your oil money to explore taking CO_2 out of the atmosphere?"

And Jens Stoltenberg answered categorically:

"I can't do that. That has to be done by industry!"

Wally tells me that he found Jens Stoltenberg's answer incredibly disappointing.

"What is needed is like 100 million dollars, yet politics shovel their responsibility to the industry. [...] That is scary. Industry has no interest in this, venture capitalists don't want to do this because the pay-off is 20, 30, 40 years away."

CO_2 capture and storage is the "dead obvious" solution to Wally. And Wally is, undoubtedly, one of the wisest guys there is in global climate science. Already today, global warming is measurable. And it is today, that the future of our globe, so beautiful and yet so fragile, lies in our hands. Yet, all we can do is hope for a change of thinking, and tell people about the science that we do.

Ice can flow like ketchup

In many ways, glaciers behave like ketchup. Once the layer of ketchup reaches a certain thickness, it will start flowing off your hot-dog to drip onto your newly washed white shirt. The same is true for glaciers.

BY **CLEMENS SPENSBERGER**, PhD STUDENT AT THE GEOPHYSICAL INSTITUTE, UiB AND THE BJERKNES CENTRE

When more and more snow piles up, at some point in time, after it has been compressed to ice, gravity will make the ice move down the mountain slopes. The further down the ice flows, the higher the temperature, and the more ice melts. So, even if the glacier does not change in length, ice is constantly flowing through the glacier from the top where the snow piles up to the bottom where ice melts away. When more snow piles up at the top than ice melts away at the bottom, the glacier will become longer and the glacier front will advance.

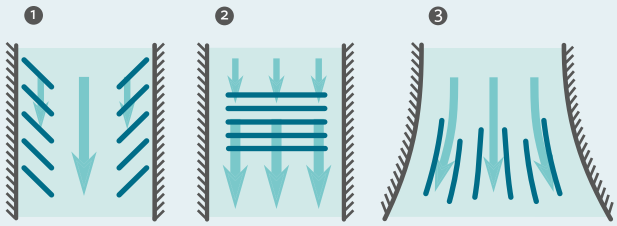
Gravity pulls on the ice all the time. Then, why doesn't the ice move faster and faster down the mountain? Also, why is there at least some of the ketchup left on your hot dog, after you've ruined your shirt? The reason is friction. It keeps both the ketchup on your hot dog and the ice from accelerating down the mountain.

The friction acts where the ice touches the rock, or where the ketchup touches the hot-dog. That means, the ice is held back along the valley floor and sides. Ice flows fastest where it is furthest away from solid ground. Differences in the ice movement because of friction are one cause for splits in the glacier. The splits are called crevasses and can be hundreds of meters long and up to meters about 50 meters deep. Friction is not the only reason for crevasses. For example, if the valley becomes steeper, the ice will flow faster and crevasses will appear. Similar things happen, if the valley is curved, or if it is getting wider. Each of the reasons creates crevasses with a distinct orientation. So, one can tell the cause of a crevasse just by its looks.

The ketchup dripping onto your shirt does not show any crevasses. But, in a few locations in the world, ice and snow drips down a cliff from what is called a hanging glacier to feed a child glacier at bottom of the cliff. Think of that the next time you eat a hot dog!

First published by ClimateSnack.com October 4. 2013

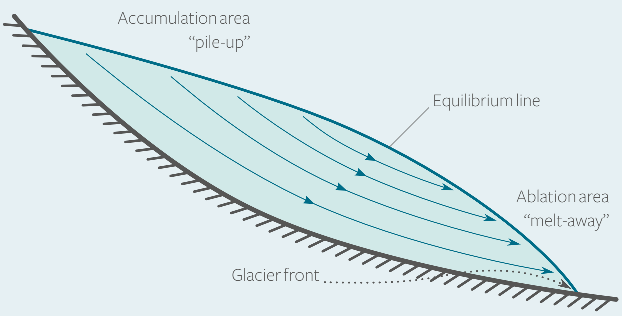
CLIMATESNACK



Different types of crevasses

1. From friction at the valley sides.
2. From the underground becoming steeper.
3. From a valley becoming wider.

The arrows show the ice movement through the glacier, the dark blue lines show crevasses.



The movement of ice through a glacier

Supphellebreen, a hanging glacier and outlet glacier of Jostedalsbreen.

September snow. Participants at the Research Communication Course at Finse. PHOTO: **KERIM NISANCIOGLU**

ResClim Activity report 2013

In 2013, the Research School in Climate Dynamics (ResClim) continued to offer high-quality training activities to our PhD students. In addition to our annual courses, we offered a new course with focus on outreach and educating the public.

BY **RAGNA BREINES**, PROJECT MANAGER

Our annual All Staff meeting took place at Sommarøya, a 40 min. drive outside of Tromsø. Here students and supervisors presented and discussed their scientific work. The students were also given a collaboration challenge. Here students were divided into groups and in 75 minutes they had to come up with a interdisciplinary project and present it. Supervisors gave an evaluation of the projects and all projects were found to be very good.

Twice a year, we offer student grants for international conferences, research stays and field/lab work. In 2013, a total of 346,990 NOK was granted.

We are looking forward following years and we will continue to offer high quality courses, workshops and financial support to our members.

ResClim
RESEARCH SCHOOL IN CLIMATE DYNAMICS

The Research School in Climate Dynamics was officially launched March 2009 and has an 8-year grant from the Research Council of Norway. Presently we have 85 PhD students and 45 supervisors enrolled, who are located in Bergen, Oslo, Tromsø and Svalbard.

COURSE NAME	LECTURER	LOCATION	DURATION	NO. PARTICIP.
Academic Writing	Daniel Soule	Oslo	3 days	13
Large Scale Turbulence in the Atmosphere and Ocean	Prof. Joe LaCasce	Oslo	10 days	9
Advanced Statistic Training	Prof. David Stepenson and Theo Economou	Bergen	3 days	18
Writing Workshop	Dallas Murphy	Bergen	5 days	12
The Advanced Climate Dynamic Course Summer school (ACDC) – Last Deglaciation	See www.uib.no/acdc	Nyksund, Lofoten	15 days	27
Scientific Communication	8 lecturers from UiB/Skolelabben/VilVite	Finse	5 days	19
Academic writing	Daniel Soule	Bergen	3 days	14

Eystein Jansen signs MoU with the University of Hawaii. Atle Nesje to the right. PHOTO: CAMILLA AADLAND

New initiatives and cooperation Agreements with Hawaii

Two Memorandums of Understanding (MoU) between the Bjerknes Centre and the University of Hawaii (UH) were signed during the first months of 2013.

With tropical research now increasing at the Bjerknes Centre, there have been discussions with UH to develop and finalize a research agreement, which will facilitate and hopefully motivate collaborative projects in the future.

Leaders in Pacific Ocean and Asia/Pacific climate research

The Meteorology and Oceanography Departments at UH are leaders in Pacific Ocean and Asia/Pacific climate research. Specific faculty expertise includes El Niño dynamics and water resource impacts, carbon cycle/climate interactions, paleoceanography, air–sea interactions, as well as statistical and dynamical downscaling.

This has led to two Memorandums of Understanding (MoU): one with the Department of Meteorology and one with the Department of Oceanography at UH. On February 5th, the two Department Chairs, Prof. Bin Wang (for Meteorology) and Prof. Kelvin Richards (for Oceanography) signed the agreements at the Manoa campus on Oahu.

Varied focus areas

The MoUs have many varied focus areas but can be summarized as:

- Paleoclimate research including glacial terminations and interglacial variability
- Dynamical and statistical downscaling
- Climate/carbon cycle interactions
- El Niño dynamics and impacts at local scales
- Decadal to multi-decadal climate variability
- Training of next generation of climate scientists
- Exchange of scientific staff and students

Engagements 2013

GLOBAL DIMENSION

IPCC: 5th Assessment report: Prof. Eystein Jansen and Senior Researcher Peter W. Thorne are Lead Authors in Working Group 1 for chapters 5 and 2, respectively. Prof. Svein Sundby is Lead Author in Working Group 2 for chapter 30. Prof. Christoph Heinze and Senior Scientist Ken Drinkwater are Review Editors in Working Groups 1 and 2, respectively. Drs. Peter Thorne, Trond Dokken, Camille Li and Jerry Tjiputra are Contributing Authors in Working Group 1. Dr. Peter Thorne is Contributing Author to Summary for Policy Makers, Technical Summary

IPCC: Special report on Extremes:
Prof. Asgeir Sorteberg is Lead Author.

Climatecode.org: Dr. Peter Thorne is Science Advisory Board member.

FOO/GOOS: Framework of Ocean Observing:
Christoph Heinze is member of the Ocean Observing Panel for Biogeochemistry.

FIX03: Truls Johannessen is a member of the Steering Committee.

GCOS: Dr. Peter Thorne is active in the following committees: Co-Chair of the Global Climate Observing System working group on the GCOS Reference Upper Air Network (and precursor Working Groups).
Editor, Global Chapter, State of the Climate annual report.
Chair of steering committee for International Surface Temperature Initiative.

Global Climate Forum: BCCR is a member of the Global Climate Forum (GCF), a non-profit organization located at PIK in Potsdam, Germany. GCF is a platform for joint studies and science-based stakeholder dialogues on climatic change and brings together representatives of different parties concerned with the climate problems.

ICES Working Group on Hydrography:
Senior Scientist Svein Østerhus is a member.
ICES Study Group on Ocean Acidification:
Dr. Are Olsen is a member.

International Geosphere-Biosphere programme (IGBP) and World Climate Research Programme (WCRP):

- Integrated Project CARBOCHANGE, coordinated by Prof. Christoph Heinze, was endorsed by the IGBP/SCOR sponsored projects SOLAS and IMBER.
- Surface Ocean Lower Atmosphere Study (SOLAS). Prof. Christoph Heinze is a member of the SSC.
- Integrated Marine Biogeochemistry and Ecosystem Research (IMBER). Senior Scientist Ken Drinkwater is an SSC member.
- Ecosystem Studies of Subarctic Seas (ESSAS). Senior Scientist Ken Drinkwater is co-chair of this IMBER regional program.
- PAGES (Past Global Changes). Prof. Ulysses Ninnemann is on the SSC of IMAGES, the marine component of PAGES.
- PAGES Arctic 2k working group. Dr. Martin Miles is a member.
- PAGES/CLIVAR joint working group. Prof. Eystein Jansen is a member.
- Climate Variability and Predictability (CLIVAR). Dr. Ken Drinkwater is a member of the Scientific Steering Group (SSG).
- Prof. Helge Drange is co-leader of the CLIVAR Working Group for Ocean Model Development (WGOCMD).
- Scientific Advisory Boards. Prof. Eystein Jansen is a member of the scientific advisory board of IC3-Climate Centre, Barcelona.
- Prof. Helge Drange is on the advisory board of MARUM, University of Bremen.

International Ocean Carbon Coordination Project (IOCCP): Dr. Are Olsen is scientific steering committee member.

International Union of Geodesy and Geophysics:
Dr. Solfrid Hjøllo is national IAPSO correspondent and member of National Committee.

INTIMATE – INTegrating Ice-core, Marine and Terrestrial records 8000-60,000 years ago:
Prof. Hilary Birks is on the Programme Management Committee and is co-leader of Working Group 4 'Climate impacts on Ecosystems'.

ICOS: Prof. Truls Johannessen is an Executive Board member 2008-2013, and member of the ICOS IRI Committee.

OceanSITES: Senior Scientist Svein Østerhus is a member of the Steering Committee.

Surface Ocean CO2 Atlas (SOCAT):
Dr. Benjamin Pfeil and Are Olsen are members of the Global Coordination Group.

US National Climate Assessment 2013:
Dr. Peter Thorne is lead author.

EUROPEAN DIMENSION

CARBONES: Prof. Christoph Heinze is member of the Scientific Advisory Board of the EU FP7 project "30-year re-analysis of CARBON fluxES and pools over Europe and the Globe" (CARBONES).

COST: Senior Scientist Svein Østerhus is a member of the European Cooperation in Science and Technology (COST) action project Everyone's Gliding Observatories Management Committee. Prof. Christoph Heinze and Dr. Caroline Roelandt are members of COST action "terrabites".

ECO2: Prof. Christoph Heinze is a member of the Scientific Advisory Board of the EU FP7 project "Sub-seabed CO2 Storage: Impact on Marine Ecosystems" (ECO2).

ECRA – European Climate Research Alliance – Prof. Eystein Jansen is a member of the executive steering committee.

ESSAC: Dr. Helga F. Kleiven is Norwegian national alternate in the Ecord Science Support and Advisory Committee (ESSAC).

IS-ENES: Prof. Christoph Heinze is a member of the Scientific Advisory Board of the EU FP7 project "Infrastructure for the European Network for Earth System Modelling" (IS-ENES).

JPI Climate – Module 1: Prof. Tore Furevik is national representative.

NERC (UK National Environmental Research Council) : Dr. Peter Thorne is Steering Committee member for Research Network on Surface Temperatures (Earthtemp).

NATIONAL DIMENSION

Research Council of Norway: KLIMAFORSK programme board: Prof. Tore Furevik, vice chairman.

Research Council of Norway: Norway–India Programme Advisory Committee:
Prof. Eystein Jansen, member.

Nansen legacy ("Arven etter Nansen")
– a national consortium to deliver a coordinated research plan for the marine environment of the Barents Sea to the Norwegian Ministry of Education and Research in March 2014. Dr. Tor Eldevik (working group leader) and Prof. Nils Gunnar Kvamstø (member of steering committee).

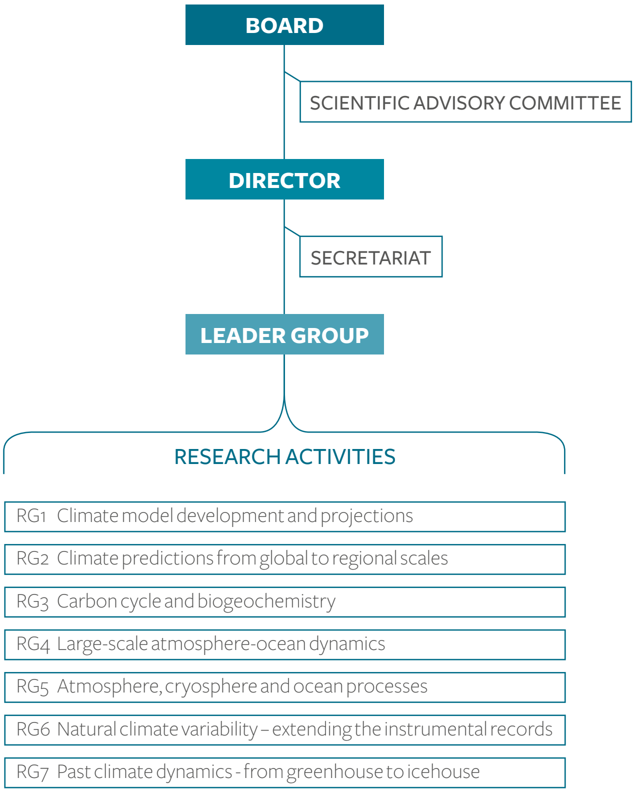
National Platform for Ocean Research, Hav21, issued by the Norwegian Ministry of Fisheries and coastal affairs:
Prof. Helge Drange is a member.

Norwegian Geophysical Society:
Dr. J. Even Ø. Nilsen is a member of the board.

SUCCESS Prof Truls Johanessen is activity leader.

Bergen Climate Forum: The climate forum is a local meeting point for people from the industry and commerce, authorities, organizations, and educational- and research institutions. It is collaboration between the Bjerknes Centre, the Bergen Chamber of Commerce and Industry and the Municipality of Bergen.

Organisation



THE LEADER GROUP

The director, the head of administration and the leaders of the Research Groups form the Leader Group, which deals with scientific and governance issues.

TORE FUREVIK	Professor (Director), Climate dynamics, UiB
HELGE DRANGE	Professor, Climate modeling, UIB
TOR ELDEVIK	Professor; Ocean processes and modeling, UiB
IGOR EZAU	Scientist, Meteorology, NERSC
CHRISTOPH HEINZE	Professor, Carbon cycle modeling, UiB & Uni Research
CAMILLE LI	Associate professor, Atmospheric dynamics, UiB
KERIM NISANCIOGLU	Associate professor, Palaeoclimatology, UiB
ARE OLSEN	Associate professor, Chemical oceanography, UiB
ODD HELGE OTTERÅ	Scientist, Climate modeling, Uni Research
ANNE BRITT SANDØ	Scientist, Ocean modeling, IMR
BJØRG RISEBROBAKKEN	Scientist, Palaeoclimatology, Uni Research
BEATRIZ BALINO	Dr. scient, Head of administration, UiB

The Boards

BOARD of DIRECTORS

ANTON ELIASSEN	Director, MET Norway (leader)
ANNE LISE FIMREITE	Pro-rector UiB
AINA BERG	Managing Director, Uni Research AS
STEIN SANDVEN	Director, NERSC
HARALD LOENG	Research Director, IMR

THE SCIENTIFIC ADVISORY COMMITTEE

ANNIE CAZENNAVE	LEGOS-CNES, France
JENS HESSELBJERG CHRISTENSEN	Danish Meterological Institute, Denmark
MICHAEL SCHULZ	University of Bremen, Germany
DETLEF STAMMER	University of Hamburg, Germany
DAVID THOMPSON	Colorado State University, USA
ANDREW WATSON	University of Exeter, UK

➊ A halo in front of the G.O. Sars. On cruise in the Greenland sea in summer 2013. PHOTO: EMIL JEANSSON

Research Groups (RG)

The research groups are functional teams of scientists, students and technical staff that implements the scientific strategy of the centre.

RG1: Climate model development and projections	LEADER (CO-LEADER)
The global climate modelling activities in Norway use the Norwegian Earth System Model – NorESM. It provides model experiments to the internationally coordinated model intercomparison project CMIP5, and analyses of climate simulations of past, present and possible future climate.	H. DRANGE, UiB (M. BENTSEN, Uni)

RG2: Climate predictions from global to regional scales	LEADER (CO-LEADER)
The climate variability in our region is heavily influenced by the oceanic and atmospheric variability in heat and moisture transports. In order to predict climate variability, it is important to understand the mechanisms behind this variability, and the interactions between sea surface temperatures, Arctic sea ice and atmospheric patterns.	A. B. SANDØ, IMR (N. KEENLYSIDE, UiB)

RG3: Carbon cycle and biogeochemistry	LEADER (CO-LEADER)
Biogeochemical processes are important in the global climate system and affect how much of man-made CO_2-emissions are taken up by the ocean and land surface. The research combines observations and modelling to determine the fate of anthropogenic CO_2 input to the atmosphere and its impact on the Earth system.	H. HEINZE, UiB (A. OLSEN, UiB)

RG4: Large-scale atmosphere-ocean	LEADER (CO-LEADER)
Winds and ocean currents, as well as the heat, moisture, and salt they carry, control the evolution of phenomena from weather systems and monsoons to ocean eddies and the Gulf Stream. To understand how these flows relate to climate, it is critical to elucidate the dynamics that maintain their time-averaged characteristics as well as the interactions that cause flow variations.	C. LI, UiB (T. ELDEVIK, UiB)

RG5: Atmosphere, cryosphere and ocean processes	LEADER (CO-LEADER)
The ocean, sea ice and atmosphere are the major components of the marine physical climate system. The processes within each medium, and those associated with the interaction between them, are crucial to the climate system. The predictive skill of the complex computer models that simulate the future climate depends critically on how they represent the key processes	I. EZAU, NERSC (L.H. SMEDSRUD, UiB)

RG6: Natural climate variability	LEADER (CO-LEADER)
The research deals with the integration of high-resolution paleoclimatic records, observations and climate model results to enhance our understanding of natural climate variability on decadal to centennial time scales.	O.H. OTTERÅ, Uni (J. BAKKE, UiB)

RG7: Past climate dynamics	LEADER (CO-LEADER)
Reconstructions and model studies of past climates are decisive to understand how and why climate has changed through time. The research encompasses dynamics of past warm and glacial climates by studying the variability of ocean circulation and temperatures, ice dynamics, atmospheric temperatures, wind forcing and mechanisms.	B. RISEBROBAKKEN, Uni (K. NISANCIOGLU, UiB)

Top: Dragonfly. Bottom left: pollen and macrofossil traps at Upsete that has trapped pollen and plant remains since 2004. Traps are emptied every autumn and its contents are analysed to show annual variation in production and deposition of fossils from different plants near the present day tree line.
Bottom right: Fjørekoll (Armeria maritime).
ALL PHOTOS: **ANNE BJUNE**

Staff 2013

SCIENTISTS

Lars	Asplin	Norway	IMR	Physical oceanography and modelling
Jostein	Bakke	Norway	UiB	Palaeoclimatology
David	Battisti	USA	UiB	Atmospheric dynamics; paleo-modelling
Richard	Bellerby	UK	Uni Research/NIVA	Biogeochemistry
Mats	Bentsen	Norway	Uni Research	Climate modelling
Laurent	Bertino	France	NERSC	Modelling and data assimilation
Ingo	Bethke	Germany	Uni Research	Ocean modelling
Bhuvan	Bhatt	Nepal	Uni Research	Meteorology
Hilary	Birks	UK	UiB	Numerical methods in palaeoclimatology
H. John B.	Birks	UK	UiB	Terrestrial biological climate proxies
Anne Elisabeth	Bjune	Norway	Uni Research	Palaeobotany
Paul	Budgell	Canada	IMR	Ocean modelling development
Youmin	Chen	China	Uni Research	Meteorology
François	Counillon	France	NERSC	Physical oceanography and modelling
Svein Olaf	Dahl	Norway	UiB	Glaciers & palaeoclimatology
Carin Andersson	Dahl	Sweden	Uni Research	Palaeoclimatology
Richard	Davy	Norway	NERSC	Climate processes; variability and change
Trond Martin	Dokken	Norway	Uni Research	Palaeoclimatology
Helge	Drange	Norway	UiB	Climate modelling
Ken	Drinkwater	Canada	IMR	Oceanography & impacts of climate change
Tor	Eldevik	Norway	UiB	Ocean processes & modelling
Igor	Esau	Russia	NERSC	Environmental boundary layers
Elisabeth	Farmer	Norway	UiB	Palaeoclimates
Ilker	Fer	Turkey	UiB	Ocean processes
Tore	Furevik	Norway	UiB	Physical oceanography
Tor	Gammelsrød	Norway	UiB	Polar oceanography
Yongqi	Gao	China	NERSC	Ocean circulation modelling
Peter	Haugan	Norway	UiB	Physical oceanography

Christoph	Heinze	Germany	UiB	Carbon cycle modelling
Solfrid	Hjøllo	Norway	IMR	Ocean circulation
Mehmet	Ilicak	Turkey	Uni Research	Oceanography
Eystein	Jansen	Norway	UiB	Palaeoclimatology
Emil	Jeansson	Sweden	Uni Research	Chemical oceanography
Truls	Johannessen	Norway	UiB	Biogeochemistry
Noel	Keenlyside	Australia	UiB	Tropical meteorology
Martin	King	Malaysia	Uni Research	Atmospheric dynamics
Helga Flesche	Kleiven	Norway	UiB	Palaeoclimatology
Trond	Kristiansen	Norway	IMR	Oceanography
Nils Gunnar	Kvamstø	Norway	UIB	Meteorology
Helene	Langehaug	Norway	Nersc	Ocean dynamics, climate modelling
Camille	Li	Canada	UiB	Atmospheric dynamics and paleoclimate
Øyvind	Lie	Norway	Uni Research	Palaeoclimatology
Torbjørn	Lorentzen	Norway	Uni Research	Economics & statistics
Kjetil	Lygre	Norway	NERSC	Biogeochemistry & modelling
Jan	Mangerud	Norway	Uni Research	Palaeoclimatology
Michel dos Santos	Mesquita	Brazil	Uni Research	Atmospheric dynamics
Martin	Miles	USA	Uni Research	Climate time series analysis
Kjell Arne	Mork	Norway	IMR	Physical oceanography
Atle	Nesje	Norway	UiB	Palaeoclimatology
Jan Even Øie	Nilsen	Norway	NERSC	Climate modelling
Ulysses S.	Ninnemann	USA	UiB	Palaeoclimatology
Kerim Hestnes	Nisancioglu	Norway	Uni Research	Palaeoclimatology & modelling
Are Christian S.	Olsen	Norway	UiB	Chemical oceanography
Abdirahman	Omar	Somalia	Uni Research	Chemical oceanography
Odd Helge	Otterå	Norway	Uni Research	Climate modelling
Stephen	Outten	UK	NERSC	Atmospheric dynamics
Pierre	Rampal	France	NERSC	Physical oceanography
Joachim	Reuder	Germany	UiB	Meteorology
Bjørg	Risebrobakken	Norway	Uni Research	Palaeoclimatology
Annette	Samuelsen	Norway	NERSC	Oceanography
Anne Britt	Sandø	Norway	IMR	Ocean modelling
Corinna	Schrum	Germany	UiB	Ocean modelling
Øystein	Skagseth	Norway	IMR	Ocean circulation
Ingunn	Skjelvan	Norway	Uni Research	Chemical oceanography
Lars Henrik	Smedsrud	Norway	UiB	Polar oceanography
Stefan	Sobolowski	USA	Uni Research	Atmospheric modelling and dynamics
Asgeir	Sorteberg	Norway	UiB	Climate modelling
Thomas	Spengler	Germany	UiB	Dynamic meteorology
John Inge	Svendsen	Norway	UiB	Palaeoclimatology
Henrik	Søiland	Norway	IMR	Ocean modelling
Peter W.	Thorne	UK	NERSC	Climate change
Jerry	Tjiputra	Indonesia	Uni Research	Carbon cycle modelling
Thomas	Toniazzo	Italy	Uni Research	Meteorology
Frode	Vikebø	Norway	IMR	Climate impacts on marine ecosystems
Zhang	Zhongshi	China	Uni Research	Paleoclimatology and modelling
Svein	Østerhus	Norway	Uni Research	Physical oceanography
Bjørn	Ådlandsvik	Norway	IMR	Physical oceanography and modelling

POSTDOCS

Muralidhar	Adakudlu	India	Uni Research	Atmospheric modelling and dynamics
Roohollah	Azad	Iran	UiB	Regional atmospheric modelling
Jon	Bergh	Sweden	NERSC	Meteorology -oceanography
Elin Darelius	Chiche	Sweden	UiB	Polar oceanography
Linling	Chen	China	NERSC	Meteorology
Laura	Ciasto	USA	UiB	Climate dynamics
Ute	Daewel	Germany	UiB	Physical oceanography
Mirjam	Glessmer	Germany	UIB	Climate dynamics
Nadine	Goris	Germany	UIB	Chemical oceanography
Anna	Hughes	UK	UiB	Paleoeclimates
Nil	Irvali	Turkey	Uni Research	Palaeoclimatology
Petra	Langebroek	Netherlands	Uni Research	Paleoeclimates
Siv Kari	Lauvset	Norway	UiB	Chemical oceanography
Yu	Lei	China	UIB	Atmospheric modelling and dynamics
Stephanie	Mayer	Germany	UiB	Meteorology
Iselin	Medhaug	Norway	UiB	Physical oceanography
Susana das Neves	Mendes	Portugal	UiB	Meteorology
Mari	Myksvoll	Norway	IMR	Physical oceanography
Caroline	Roelandt	Belgium	UiB	Terrestrial Biogeochemical modelling
Jörg	Schwinger	Germany	UiB	Carbon cycle modelling
Mao-Lin	Shen	China	Uni Research	Physical oceanography and modelling
Lingling	Suo	China	NERSC	Climate dynamics
Ellen	Viste	Norway	UiB	Meteorology
Kjetil	Våge	Norway	UiB	Physical Oceanography
Marius	Årthun	Norway	UiB	Ocean modelling

PhD CANDIDATES

Helle Augdal	Botnen	Norway	UiB	Biogeochemistry
Kjersti	Daae	Norway	UiB	Physical oceanography
Pierre	de Wet	South Africa	UiB	Oceanography/climate dynamics
Marie	Eide	Norway	UiB	Chemical oceanography
Vivian Astrup	Felde	Norway	Uni Research	Terrestrial plant biodiversity
Eirik Vinje	Galaasen	Norway	UiB	Palaeoclimates
Marthe	Gjerde	Norway	UiB	Palaeoclimates
Stephanie	Gleixner	Germany	UiB	Meteorology
Mari Fjalstad	Jensen	Norway	UiB	Palaeoclimates
Stefan	Keiderling	Norway	UiB	Meteorology
Erlend Moster	Knudsen	Norway	UiB	Oceanography
Vidar	Lien	Norway	IMR	Regional ocean modelling
Sigrid	Lind	Norway	IMR	Oceanography
Tor L.	Mjell	Norway	UiB	Palaeoclimates

Anne	Morée	Netherlands	UiB	Biogeochemistry & modelling
Aleksi	Nummelin	Finland	UiB	Palaeoclimates
Ingrid	Onarheim	Norway	UiB	Physical oceanography
Lea Toska	Oppedal	Norway	Uni Research	Palaeoclimatology
Mathew	Reeve	USA	UiB	Meteorology
Mari Ingeborg	Sandvik	Norway	UiB	Meteorology
Anna	Silyakova	Russia	Uni Research	Biogeochemistry
Svetlana	Sorokina	Russia	NERSC	Meteorology
Clemens	Spensberger	Germany	UiB	Meteorology
Lea	Svendsen	Norway	UiB	Meteorology
Silje	Sørland	Norway	UiB	Oceanography
Andrea	Tegzes	Hungary	Uni Research	Palaeoclimates
Amandine	Tisserand	France	Uni Research	Palaeoclimates
Kristian	Vasskog	Norway	UiB	Palaeoclimates

TECHNICAL STAFF

Lukas	Becker	Germany	Uni Research	Palaeoclimatology
Dagfinn	Bøe	Norway	Uni Research	Palaeoclimatology
Tor	de Lange	Norway	UiB	Chemical oceanography
Alok	Gupta	India	Uni Research	Climate modelling
Odd Reidar	Hansen	Norway	UiB	Palaeoclimatology
Ingeborg	Helvik	Norway	Uni Research	Paleobotany
Catherine	Jenks	UK	UiB	Paleobotany
Espen	Karlsen	Norway	Uni Research	Meteorology; oceanography
Solveig	Kringstad	Norway	UiB	Chemical oceanography
Benjamin	Pfeil	Germany	Uni Research	Data manager
Jørund	Strømsøe	Norway	Uni Research	Palaeoclimatology
Rune Egil	Søraas	Norway	Uni Research	Palaeoclimatology
Aslaug Skålevik	Valved	Norway	Uni Research	Meteorology, oceanography

ADMINISTRATION

Beatriz	Balino	Norway	UiB	Head of administration SKD
Lars	Fagerli	Norway	Uni Research	Financial officer
Birgit	Falch	Norway	Uni Research	Research coordinator
Kim-André	Herøy	Norway	Uni Research	Senior Secretary
Jill	Johannessen	Norway	Uni Research	Head of communications
Beate	Klementsen	Norway	Uni Research	HR Manager
Charla Melander	Olsen	USA	Uni Research	Administrative consultant
Gudrun	Sylte	Norway	Uni Research	Head of communications

BCCR scientists visiting INSMET, the Meteorological Institute in Cuba in spring 2013 for a workshop in the research project XCUBE dealing with the future of climate extremes in the Caribbean.

↑ The Meteorological institute.
→ The Meteorological institute with a view of Havana.
PHOTOS: **MICHEL DOS SANTOS MESQUITA**

External funding: 2013 was a record year

In 2013 a considerable number of research projects were about to wind down. So when the last call of the NORKLIMA program from the Research Council of Norway (RCN) was released, a concerted action was taken to renew the external funding in order sustain and enhance the level of scientific activity so far. And the effort bore fruits: nine out of thirteen successful projects were granted to Bjerknes affiliated scientists, about 100 mill NOK to be spent the next 4-5 years.

Eystein Jansen, director of the BCCR until December 2013, was optimist about the outcome, but these results exceeded all expectations:

”This shows that we have the best projects and the best ideas. Many of the new project leaders started their scientific career at the Bjerknes Centre. With this amount of external funding we can increase the activity at the centre, and engage new young talents” Eystein Jansen said to the university newspaper På Høyden in June.

Additional 30 mill NOK were secured in the form of five grants through RCN´s funding scheme for independent projects FRIPRO, three of which allocated to “Young researcher talents”.

BCCR was also successful in the competition for international funding, acquiring a 17 mill NOK grant from the Nordic Top Research Initiative (GREENICE) and a 9 mill Euro Collaborative Project under the last call from FP7 (PREFACE).

Finally, the Bjerknes Centre allied with colleagues from Denmark won a prestigious ERC Synergy grant. “Ice2Ice” was among the thirteen successful applications out of a total of 449, and the Bjerknes Centre is the first Norwegian institution that succeeded in this fierce competition. The grant brings a total of 12,5 mill Euros over a period of 5 years and will allow the engagement of 10 new recruiting positions at UiB and Uni Research. Ice2Ice co-PIs in Bergen are Eystein Jansen and Kerim Nisancioglu.

Thus, the grounds are set for the Bjerknes staff list to grow from 2014 and onwards.

➊ Six project leaders celebrating the results from the NORKLIMA call in June.
From left: Noel Keenlyside (EPOCASA), Emil Jeansson (VENTILATE), Are Olsen (SNACS) with his son Even, Tor Eldevik (NORTH), John Inge Svendsen (EISCLIM) and Christoph Heinze (EVA).
PHOTO: CAMILLA AADLAND

Selected Publications

Bjerknes researchers published over 120 articles in international peer reviewed journals in 2013.
For a complete listing, please visit www.bjerknes/publications. Bjerknes scientists are indicated with full names in bold.

1. **Bader, Jürgen**, Flügge, M., **Kvamstø, Nils G.**, **Mesquita, Michel D. S.** and Voigt, A. (2013): Atmospheric winter response to a projected future Antarctic sea-ice reduction: a dynamical analysis. *Climate Dynamics*, 40, 2707–2718.
2. **Bakke, Jostein, Trachsel, Mathias, Kvisvik, Bjørn Christian, Nesje, Atle** and Lyså, A. (2013): Numerical analyses of a multi-proxy data set from a distal glacier-fed lake, Sørsendalsvatn, western Norway. *Quaternary Science Reviews*, 73, 182–195.
3. **Bjune, Anne Elisabeth**, Helvik, I. and **Birks, H. John B.** (2013): The Fagus sylvatica forests in the Larvik region, south-eastern Norway – their origin and history. *Vegetation History and Archaeobotany*, 22, 215–229.
4. Bopp, L., Resplandy, L., Orr, J. C., Doney, S. C., Dunne, J. P., Gehlen, M., Halloran, P., **Heinze, Christoph**, Ilyna, T., Séférian, R., **Tjiputra, Jerry** and Vichi, M. (2013): Multiple stressors of ocean ecosystems in the 21st century: projections with CMIP5 models. *Biogeosciences*, 10, 6225–6245.
5. **Botnen, Helle Augdal, Omar, Abdirahman**, Aavatsmark, I., Alendal, G. and **Johannessen, Truls** (2013): PVTx properties of a two-phase CO2 jet from ruptured pipeline. *Energy Procedia*, 37, 3031–3038.
6. Boyle, J., Chiverrell, R., Plater, A., Thrasher, I., Bradshaw, E., **Birks Hilary H.** and **Birks, H. John B.** (2013): Soil mineral depletion drives early Holocene lake acidification. *Geology*, 41, 415–418. doi:10.1130/G33907.1.
7. **Bentsen, Mats, Bethke, Ingo**, Debernard, J. B., Iversen, T., Kirkevåg, A., Seland, Ø., **Drange, Helge, Roelandt, Caroline**, Seierstad, I. A., Hoose, C. and Kristjansson, J. E. (2013): The Norwegian Earth System Model, NorESM1-M – Part 1: Description and basic evaluation of the physical climate. *Geoscientific Model Development*, 6, 687–720.
8. **Davy, Richard** and **Igor Esau** (2013): Surface air temperature response in global climate models, *Atmospheric Science Letters*, on-line first, doi: 10.1002/asl2.456.
9. **Dokken, Trond Martin, Nisancioglu, Kerim Hestnes, Li, Camille, Battisti, David Stephen** and Kissel, C. (2013): Dansgaard-Oeschger cycles: Interactions between ocean and sea ice intrinsic to the Nordic seas. *Paleoceanography*, 28, 491–502.
10. **Drinkwater, Ken, Miles, Martin, Medhaug, Iselin, Otterå, Odd Helge**, Kristiansen, T., **Sundby, Svein** and **Gao, Yongqi** (2013): The Atlantic Multidecadal Oscillation: its manifestations and impacts with special emphasis on the region north of 60°N. *Journal of Marine Systems*, in press, doi:10.1016/j.jmarsys.2013.11.001.
11. **Eldevik, Tor** and Nilsen, **Jan Even Ø.** (2013): The Arctic/Atlantic thermohaline circulation. *Journal of Climate*, doi: http://dx.doi.org/10.1175/JCLI-D-13-00305.1.
12. **Esau, Igor**, Alexeev, V., Repina, I. and **Sorokina, Svetlana** (2013): Contrasting vertical structure of recent Arctic warming in different data sets. *Atmospheric and Climate Sciences*, 3, 1-5, doi:10.4236/acs.2013.31001.
13. **Frigstad, Helene**, Andersen, T., Hessen, D. O., **Jeansson, Emil**, Skogen, M., Naustvoll, L.-J., **Miles, Martin W., Johannessen, Truls** and **Bellerby, Richard G. J.** (2013): Long-term trends in carbon, nutrients and stoichiometry in Norwegian coastal waters: evidence of a regime shift. *Progress in Oceanography*, doi: http://dx.doi.org/10.1016/ j.pocean.2013.01.006.
14. Gulev, S. K., Latif, M., **Keenlyside, Noel**, Park, W. and Koltermann, K. P. 2013: North Atlantic Ocean control on surface heat flux at multidecadal timescales, *Nature*, 499, 464–467.
15. Guo, Dong, **Gao, Yongqi, Bethke, Ingo, Gong**, D., Johannessen, O. M. and Wang, H. (2013): Mechanism on how the spring arctic sea ice impacts the East Asian summer monsoon. *Journal of Theoretical and Applied Climatology*, 115, 107–119.
16. Hall, A. M. Ebert, K., Kleman, J., **Nesje, Atle** and Ottesen, D. (2013): Selective glacial erosion on the Norwegian passive margin. *Geology*, 41, 1203-1206, doi: 10.1130/G34806.1.
17. **Heinze, Christoph** and Gehlen, M. (2013): Modeling Ocean Biogeochemical Processes and the Resulting Tracer Distributions (Ch. 26), in Siedler, G., Griffies, S., Gould, J. and Church, J. (Eds.): *Ocean Circulation and Climate, 2nd Ed. A 21st century Perspective*, Elsevier, 667–694 (peer reviewed).
18. Iversen, T., **Bentsen, Mats, Bethke, Ingo**, Debernard, J. B., Kirkevåg, A., Seland, Ø., **Drange, Helge**, Kristjansson, J. E., **Medhaug, Iselin**, Sand, M. and Seierstad, I. A. (2013): The Norwegian Earth System Model, NorESM1-M - Part 2: Climate response and scenario projections. *Geoscientific Model Development*, 6, 389-415.
19. **Keenlyside, Noel S.**, Ding, H, and Latif, M. (2013): Potential of equatorial Atlantic variability to enhance El Niño prediction. *Geophysical Research Letters*, 40, 2278–2283.
20. **Langehaug, Helene R.**, Geyer, F., **Smedsrud, Lars Henrik** and **Gao, Yongqi** (2013): Arctic sea ice decline and ice export in the CMIP5 historical simulations. *Ocean Modelling*, 71, 114–126, doi: 10.1016/j.ocemod.2012.12.006, 2013.
21. **Lauvset, Siv Kari**, Chierici, M., **Counillon, Francois, Omar, Abdirahman**, Nondal, G., Johannessen, Truls and Olsen, Are (2013): Annual and seasonal fCO2 and air-sea CO2 fluxes in the Barents Sea. *Journal of Marine Systems*, 39, L12605, doi:10.1029/2012GL051012.

22. **Lien, Vidar S., Vikebø, Frode B.** and **Skagseth, Øystein** (2013): One mechanism contributing to co-variability of the Atlantic inflow branches to the Arctic. *Nature Communications*, 4, 1488, doi: 10.1038/ncomms2505.

23. Lunde, T. M., Korecha, D., Loha, E., **Sorteberg, Asgeir** and Lindtjorn, B. (2013): A dynamic model of some malaria-transmitting anopheline mosquitoes of the Afrotropical region. I. Model description and sensitivity analysis. *Malaria Journal* 12:28 doi:10.1186/1475-2875-12-28.

24. **Mangerud, Jan**, Goehring, B. M., **Lohne, Øystein S., Svendsen, John Inge** and Gyllencreutz, R. (2013): Collapse of marine-based outlet glaciers from the Scandinavian Ice Sheet. *Quaternary Science Reviews*, 67, 8–16.

25. Omrani, N.-E., **Keenlyside, Noel S., Bader, Jürgen** and Manzini, E. (2013): Stratosphere key for wintertime atmospheric response to warm Atlantic decadal conditions. *Climate Dynamics*, 42, 649–663.

26. **Outten, Stephen, Davy, Richard** and **Esau, Igor** (2013): Eurasian winter cooling: Intercomparison of Reanalyses and CMIP5 data sets. *Atmospheric and Oceanic Science Letters* , 6(5), 324–331, doi:10.3878/j.issn.1674-2834.12.0112

27. **Outten, Stephen** and **Esau, Igor** (2013): Extreme winds over Europe in the ENSEMBLES regional climate models. *Atmospheric Chemistry and Physics*, 13, 5163-5172, doi:10.5194/acp-13-5163-2013.

28. **Pfeil, Benjamin, Olsen, Are**, Bakker, D. C. E., Hankin, S., Koyuk, H., Kozyr, A., Malczyk, J., Manke, A., Metzl, N., Sabine, C. L., Akl, J., Alin, S. R., Bates, N., **Bellerby, Richard G. J.**, Borges, A., Boutin, J., Brown, P. J., Cai, W.- J., Chavez, F. P., Chen, A., Cosca, C., Fassbender, A. J., Feely, R. A., González-Dávila, M., Goyet, C., Hales, B., Hardman-Mountford, N., **Heinze, Christoph**, Hood, M., Hoppema, M., Hunt, C. W., Hydes, D., Ishii, M., **Johannessen, Truls**, Jones, S. D., Key, R. M., Körtzinger, A., Landschützer, P., **Lauvset, Siv Kari**, Lefèvre, N., Lenton, A., Lourantou, A., Merlivat, L., Midorikawa, T., Mintrop, L., Miyazaki, C., Murata, A., Nakadate, A., Nakano, Y., Nakaoka, S., Nojiri, Y., **Omar, Abdirahman M.**, Padin, X. A., Park, G.-H., Paterson, K., Perez, F. F., Pierrot, D., Poisson, A., Ríos, A. F., Santana-Casiano, J. M., Salisbury, J., Sarma, V. V. S. S., Schlitzer, R., Schneider, B., Schuster, U., Sieger, R., **Skjelvan, Ingunn**, Steinhoff, T., Suzuki, T., Takahashi, T., Tedesco, K., Telszewski, M., Thomas, H., Tilbrook, B., **Tjiputra, Jerry**, Vandemark, D., Veness, T., Wanninkhof, R., Watson, A. J., Weiss, R., Wong, C. S. and Yoshikawa-Inoue, H. (2013): A uniform, quality controlled Surface Ocean CO_2 Atlas (SOCAT). *Earth System Science Data*, 5, 125–143, doi:10.5194/essd-5-125-2013.

29. **Richter, Kristin**, Riva, R. E. M. and **Drange, Helge** (2013): Impact of self-attraction and loading effects induced by shelf mass loading on projected regional seal level rise. *Geophysical Research Letters*, 40, doi:10.1002/grl.50265.

30. **Silyakova, Anna, Bellerby, Richard**, Schulz, K. G., Czerny, J., Tanaka, T., **Nondal, Gisle**, Riebesell, U., Engel, A., **de Lange, Tor** and Ludvig, A. (2013): Pelagic community production and carbon-nutrient stoichiometry under variable ocean acidification in an Arctic fjord. *Biogeosciences*, 10, 4847–4859.

31. **Skogen, Morten D., Olsen, Are, Børsheim, Knut Y., Sandø, Anne Britt** and **Skjelvan, Ingunn** (2013): Modelling ocean acidification in the Nordic and Barents Seas in present and future climate. *Journal of Marine Systems*, doi: 10.1016/j.jmarsys.2013.10.005.

32. **Smedsrud, Lars Henrik, Esau, Igor, Ingvaldsen, Randi, Eldevik, Tor, Haugan, Peter M., Li, Camille, Lien, Vidar Surén, Olsen, Are, Omar, Abdirahman, Otterå, Odd Helge, Risebrobakken, Bjørg, Sandø, Anne Britt**, Semenov, V. A. and **Sorokina, Svetlana** (2013): The role of the Barents Sea in the Arctic climate system. *Reviews of Geophysics*, 51, 415–449.

33. **Svendsen, Lea, Kvamstø, Nils Gunnar and Keenlyside, Noel S.** (2013): Weakening AMOC connects Equatorial Atlantic and Pacific interannual variability. *Climate Dynamics*, DOI 10.1007/s00382-013-1904-8.

34. **Suo, Lingling, Otterå, Odd Helge, Bentsen, Mats, Gao, Yongqi**, and Johannessen, O. M. (2013): External forcing of the early 20th century Arctic warming. *Tellus, A*, 20578, http://dx.doi.org/10.3402/tellusa.v65i0.20578.

35. **Søiland, H.** and T. Rossby, (2013): On the structure of the Lofoten Basin Eddy. Journal of *Geophysical Research Oceans*, 118, 4201-4212, doi:10.1002/jgrc.20301.

36. **Tisserand, Amandine Aline, Dokken, Trond Martin**, Waelbroeck, C., Gherardi, J.-M., Scao, V., Fontanier, C. and Jorissen, F. (2013): Refining benthic foraminiferal Mg/Ca-temperature calibrations using core-tops from the western tropical Atlantic: Implication for paleotemperature estimation. *Geochemistry Geophysics Geosystems*, 14, 929–946.

37. **Tjiputra, Jerry, Roelandt, Caroline, Bentsen, Mats**, Lawrence, D. M., Lorentzen, **Torbjørn, Schwinger, Jörg**, Seland, Ø. and **Heinze, Christoph** (2013): Evaluation of the carbon cycle components in the Norwegian Earth System Model (NorESM). *Geoscientific Model Development*, 2, 301–325.

38. **Vasskog, Kristian**, Waldmann, N., Bondevik, S., **Nesje, Atle**, Chapron, E. and Ariztegui, D. (2013): Evidence for Storegga tsunami run-up at the head of Nordfjord, western Norway. *Journal of Quaternary Science*, 28 (4) 391–402.

39. **Viste, Ellen**, Korecha, D. and **Sorteberg, Asgeir** (2013): Recent drought and precipitation tendencies in Ethiopia. *Journal of Theoretical and Applied Climatology*, 112, 535–551.

40. **Viste, Ellen** and **Sorteberg, Asgeir** (2013): Moisture transport into the Ethiopian highlands. *International Journal of Climatology*, 33, 249–263.

41. **Våge, Kjetil**, Pickart, R. S., Spall, M. A., Moore, G. W. K., Valdimarsson, H., Torres, D. J., Erofeeva, S. Y. and **Nilsen, Jan Even Ø.** (2013): Revised circulation scheme north of the Denmark Strait. *Deep Sea Research Part I*, 79, doi:10.1016/j.dsr.2013.05.007.

42. Wang, T., H. J. Wang, **Otterå, Odd Helge, Gao, Yongqi, Suo, Lingling, Furevik, Tore** and Yu, L. (2013): Anthropogenic agent implicated as a prime driver of shift in precipitation in eastern China in the late 1970s. *Atmospheric Chemistry and Physics*, 13, 12,433–12,450.

43. **Zhang, Zhongshi, Nisancioglu, Kerim** and **Ninnemann, Ulysses** (2013): Increased ventilation of Antarctic deep water during the warm mid-Pliocene. *Nature Communications*, 4, 1499 doi: 10.1038/ncomms2521.

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Christmas with the penguins

December 2012 through January 2013, Elin Darelius, Mari Jensen, Kjetil Våge and Helge Bryhni at the UiB joined a two month cruise in the Weddell Sea, to study the deep and extremely cold ocean currents emerging from the cavities below the floating ice shelves fringing the Antarctic continent. The Bjerknes researchers boarded the research ship Ernest Shackleton (seen in the distance) to join fellow british researchers and a lot of penguins for Christmas. The instruments Darelius and her colleagues placed on the Antarctic continental shelf in the Weddell Sea were in the early 2014 picked up by Svein Østerhus, Uni Research (photo on the right). This research is part of a long lasting Norwegian tradition, going back to the 1970's when the cold current was discovered by researchers from the University of Bergen. In Antarctica on cruise December 2013 – March 2014, Svein Østerhus prolonged the tradition when his observatory was lowered to the continental shelf, constructed to measure deep ocean currents for many years to come.

PHOTO: ELIN DARELIUS

PHOTO: SVEIN ØSTERHUS