

Technical University of Denmark



## Identification and Application of Surrogate Models for Urban Drainage Modelling

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*Published in:*

4th nordic conference on climate change adaptation "from research to actions and transformation"

*Publication date:*

2016

*Document Version*

Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*

Thrysoe, C., Borup, M., & Arnbjerg-Nielsen, K. (2016). Identification and Application of Surrogate Models for Urban Drainage Modelling. In 4th nordic conference on climate change adaptation "from research to actions and transformation": Book of abstracts (pp. 37-37). [47] Bergen, Norway.

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4<sup>TH</sup> NORDIC CONFERENCE ON CLIMATE CHANGE ADAPTATION  
“From Research to Actions and Transformation”  
August 29-31 2016 in Bergen, Norway

# BOOK OF ABSTRACTS



# 1

## Regional Climate Change induced Risks on Electricity Distribution Networks in Germany

*Marius Stankoweit*

Besides its essential role towards a carbon-neutral electricity generation, the reliability of the energy sector is of vital importance for the proper functioning of a society and its economy. Therefore, it is regarded as part of a country's critical infrastructure, which is attributed to all assets of such essential importance. A long-lasting and large-scale electricity blackout could also lead to the collapse of many other critical infrastructures. Therefore, the vulnerability of the energy sector due to climate change increasingly becomes a matter of research.

Historically, grid disruptions occurred mainly in the distribution networks, most frequently caused by wind conditions. Wind- and ice-loads acting on electricity grid infrastructure have been identified being one of the largest sensitivities of the electricity system to climate change.

The German "Energiewende", characterized by an increasing share of decentralized small-scale renewable energy sources feeding directly into the regional distribution grids, triggers the need for reconfiguring the distribution grids and extension requirements between 80,000 to up to 380,000 km (depending on the scenario considered) between 2009 and 2020. Due to the long life expectancy of these investments of typically 50 to 80 years, the planning of these infrastructures should consider the potential impacts of changes in regional climate conditions on the requirements of the planned infrastructure. Therefore, the system grid infrastructure has to be designed such that it is adapted to future climatic conditions, since maladaptation of the grid infrastructure may lead to deadweight losses, either due to stranded investments or due to losses resulting from recurring outages of the grid infrastructure.

The work combines three streams of information to investigate the county-specific physical and economic vulnerability of the German electricity distribution networks due to climate change. Based on data on the characteristics of the regional distribution networks and regional climate data on wind- and ice-loads, a parameter that quantifies a county-specific sensitivity to climate change is determined. By matching this sensitivity parameter with the follow-up costs from an electricity outage (value of lost load), a county-specific risk value is obtained. The value of lost load is determined from a macroeconomic model.

The analysis shows how the sensitivity of the German electricity distribution grid to extreme-weather-events differs geographically. The determination of county-specific risk levels enables to analyze, whether regional adaptation levels differ according to (i) their economic follow-up costs of a blackout and (ii) the probability of the occurrence of extreme wind- and ice-load events. Consequently, it enables to identify those counties with a high risk exposure, and enables to consider this information in the current scenario development for the reconfiguration and extension of the distribution networks.

## 5

# Interdisciplinary and Intergenerational climate dialogues for the Svalbard Fisheries Protection Zone

*Dorothy Dankel, Rachel Tiller and Yajie Liu*

The climate is changing in the Arctic and projections by the IPCC suggests valuable marine resources are migrating further north. What does this mean for fishers, for tourists, for international politics and future communities in the far north, and for the Svalbard fisheries protection zone and Norwegian sovereignty in the area?

The REGIMES project draws on the foremost marine climate modellers from the William Cheung lab at the University of British Columbia in Vancouver, Canada to create future climate scenarios of the Arctic Ocean. The REGIMES team further builds on these models through expert knowledge on various ecosystem services, as well as stakeholder dialogues to explore changes on the perceived vulnerability and adaptability at sector and society levels under different climate scenarios.

Our focus is through the geographical, ecological, social, economic and political lens of the Svalbard Fisheries Protection Zone (SFPZ), where we expect future climate changes will have great impact. The zone was created in 1976 and Norway has taken a proactive role in institutionalizing its management claim by maintaining a strong Coast Guard presence and imposing Norwegian environmental regulations in the zone. Despite this, the status of the SFPZ has remained disputed by most nations.

Stakeholder groups in workshops will discuss how the ecosystem service scenarios may affect them in terms of challenges, opportunities and adaptability. The REGIMES team will then assess stakeholders' adaptive capacities and vulnerabilities by combining the environmental modeling results with stakeholder perception scenarios and models of sustainable future management of the SFPZ.

The REGIMES project also focuses on a 3-year iterative dialogue with students at the prestigious Amalie Skram Videregående Skole in Bergen. This collaboration will test a digital role-playing game that will be used intra- and inter-generationally to elucidate new narratives of climate adaptation.

## 6 Co-producing climate knowledge with local communities: Lessons from Bangladesh

*Scott Bremer*

Climate adaptation researchers and practitioners increasingly call for more localised research, recognising the specificity of climate and its impacts in a particular 'place'. This transition to place-based adaptation has prompted thinking around the limits of current modes of climate science to support adaptation at this scale. How can climate sciences provide information at a spatial and temporal scale useful for local communities? Indeed, to what extent is science even trusted as legitimate in these communities?

Authors across various disciplines have advocated alternative modes of 'co-producing' climate knowledge, through partnerships between scientific and local communities. Co-production can take many different forms but presents a common challenge; to animate meaningful collaboration between different knowledge holders in producing knowledge fit for adaptive action in a place. Rising to this challenge demands a genuine transformation in how we organise, practice, communicate and value climate science research. We can infer lessons for climate science from where co-production has been put into action.

The TRACKS research project is giving effect to climate knowledge co-production with communities in the vulnerable northeast of Bangladesh. The project nests climate science in the on-going local discussions of weather and its impacts. Scientific inquiry is steered by local problem-framings, while being complimented and challenged by local and traditional knowledge. Together, scientists and local people are identifying areas for future research, designing an accordant portfolio of indicators and measuring these indicators as a team of 'citizen scientists'.

Processes of co-production are distinctive to their context, but they do offer up lessons for how similar approaches could be effected elsewhere. In this talk I will draw some lessons from the TRACKS experience in Bangladesh that might be applicable to the Nordic context.

## 7

# Co-producing climate knowledge applying citizen science approach in northeast Bangladesh

*M. Mahfujul Haque, M. Saifullah Bin Aziz, Zakia Naznin and Scott Bremer*

Climate change is a complex issue encompassing various environmental, cultural and political phenomena that are reshaping ways of thinking about the future world. Bangladeshi agrarian communities present one important case; demanding attention to the changing relationship between these agrarian communities and their climate, and challenging their ways of knowing this climate. While these communities can be said to draw on a significant store of local and traditional knowledge of the weather and its impacts, as well as meteorological science, they are being forced to recognise the limitations of this knowledge in the face of rapid climatic changes. Arguably, these communities need to re-learn the climatic rhythms that steer their lives. This calls for on-going, adaptive measurement of climate indicators drawing on the full diversity of knowledge systems. This calls for genuine citizen science.

Citizen science enlists a network of non-scientist volunteers to help collect and analyze data in many different ways (Cohn, 2008). The past 20 years has seen citizen science grow in popularity for engaging citizens in helping scientists address complex issues. Early citizen science projects explored a diversity of issues, ranging from the identification and classification of birds or stars, to the measurements of fossils. The use of citizen science in weather and climate studies (e.g. measuring precipitation) is a more recent trend (Lowry and Fienen, 2012). The use of citizen science approach for measuring indicators of climate change in developing countries is becoming popular because it is cost effective, it permits gathering data over a large geographic and temporal scale, and it improves the 'broader impact' of the research by involving citizens (Gura, 2013). Citizen science may offer a way for facilitating interaction between scientific and local communities to jointly learn about a new climate.

The TRACKS project aims to bring science and society together in an interacting platform to co-produce high quality knowledge of climate variability and its impacts in the northeast Bangladesh, one of the climatically vulnerable regions of Bangladesh. The TRACKS research approach emphasizes the learning and capacity building associated with citizen science, engaging stakeholders alongside scientists as an 'extended peer community' for designing the research, carrying out the measurements, logging data, and undertaking some analysis. Following interviews in the project area, about fifty citizen scientists were selected according to their different backgrounds, their level of climate knowledge, and their willingness to participate in the research process. They will measure indicators for one full year from mid-April, according to the traditional Bangla calendar.

In this talk we will present how the TRACKS citizen science team worked with climate scientists to design a portfolio of climate indicators in March 2016, and present their progress in measuring these indicators since April.

## 8

# Mobilising climate knowledge for adaptation in north-east Bangladesh using a ‘narrative’ approach

*Nabir Mammun, Scott Bremer, M. Mahfujul Haque, Anne Blanchard, Mathew Still-er-Reeve and Endre Tvinnereim*

Bangladesh is witnessing a shift toward community-level adaptation in recognition of the particular climate vulnerabilities faced in different communities in different places across the country. This shift is accompanied by awareness of the limits of science-based adaptation at the local scale, and exploring of alternative approaches to mobilizing high quality climate knowledge tailored to local adaptation, including varying notions of ‘co-production’. One way of conceiving of climate knowledge co-production is as a partnership between scientific and local communities, to exchange, appraise, co-construct and apply knowledge ‘on the ground’. Co-production recognizes that relevant climate knowledge is not concentrated within any one group of actors but diffused throughout an entire community, according to different ways of knowing, including local and traditional knowledge systems. One key challenge is how to elicit local and traditional knowledge systems for co-production, when this knowledge is often not communicated in a formal and explicit way, but rather remains internal and personal, or tacit, to knowledge-holders.

In this presentation we will present an overview of the narrative interview approach designed by the TRACKS research project to elicit the climate knowledge of people in communities in northeast Bangladesh. We undertook a series of 238 interviews with different actors across four study sites, according to a semi-structured, narrative-based framework that invited interviewees to share their stories on climate variability and its impacts on their life. Interviewees were identified through a stakeholder mapping process with an emphasis on accessing as diverse perspectives possible, resulting in a stock of very different experiences, knowledge and stories with the weather. We will present some examples of these stories and how they can contribute to a co-production process. The success in TRACKS shows that the narrative approach presents a promising methodological tool for understanding the climate as locally experienced and socio-cultural phenomena, and to mobilize high quality knowledge in support of adaptation.



## 9

# How to evaluate the success of a climate adaptation research project?

*Anne Blanchard and Synnøve Kvamme*

It is important to integrate an ongoing evaluation component in climate adaptation research projects for several reasons: for the accountability of the project, and to justify the political and economic support provided; for establishing causality between the project and improved collective decision-making and outcomes; and to learn lessons about implementing adaptation projects in different contexts. Arguably, each evaluation framework needs to be tailored to the objectives, context and means of every climate adaptation project.

The TRACKS project is a particular type of adaptation project, focused on how we mobilise a body of high-quality knowledge to support local adaptation actions in northeast Bangladesh. The focus is on learning for adaptation, through a participatory process that assembles an 'extended peer-community' within two study areas in northeast Bangladesh; including a broad range of local stakeholders, from rice farmers and fishermen to medical doctors and journalists, alongside the natural scientists of the TRACKS consortium. This peer community is working together to improve understanding of local climate variability and its impacts, and discuss what is useful knowledge for adaptation. For us in the TRACKS project, this demands both an internal evaluation within the consortium, and an external evaluation of how we affect change within the extended peer community and beyond.

The internal evaluation is particularly interested in cooperation across the disciplines (natural sciences, social and human sciences and agricultural sciences) and across the cultures (partners in Bangladesh and in Norway) present in TRACKS. To this aim, the project has integrated an ongoing evaluation work package from the start of the project. This is structured around tools to facilitate interdisciplinarity among consortium members, in parallel with interviews with these members, to elicit critical perspectives on our internal cross-disciplinary and cross-cultural interactions.

The external evaluation adopts an adaptive governance lens. We drew on themes in this literature in designing interviews, which we conducted with some members of the extended peer community. In this way, we were able to elicit what they consider to be some of the key challenges of producing useable climate knowledge and how they would measure the success of the project in overcoming these challenges. This top-down, theory-driven meets bottom-up community-led approach has resulted in an evaluation framework for measuring impacts within the external peer community.

In this talk, we will expand on the evaluation work in the TRACKS project, presenting some of the findings from the internal evaluation, and our work to develop a framework for the external evaluation.



# 10

## **Perceptions of climate change in rural Bangladesh: Analysing narrative interviews using qualitative and quantitative methods.**

*Endre Tvinnereim and Scott Bremer*

The TRACKS project seeks to produce arenas where scientific and local communities may co-produce knowledge about location-specific climate change impacts and potential community-based adaptation strategies. Narrative interviews constitute one novel method for eliciting perceptions of climate change and uncover the local knowledge required for effective climate change adaptation. This paper presents a framework for analysing the transcripts from such narrative interviews using a combination of qualitative and quantitative methods. We take transcripts as the unit of analysis and induce latent dimensions or topics from relative word frequencies in each document using structural topic modelling. Food security, disaster episodes and effects on infrastructure are typical topics. We then cross-validate these results with qualitative analysis and categorisation of the same responses. Finally, we examine the correlation of topic prevalence (which respondents emphasise which topics) with demographic information.

## **Future projections of rainfall over North-East Bangladesh: Bayesian Model Averaging of Regional Climate Models**

*Md. Abul Basher, A.K.M Saiful Islam and Mathew Stiller-Reeve*

Climate change has the potential to strongly impact the diverse agricultural production of north-east Bangladesh. Previous studies have considered future climate change in this region using the results from the Coupled Model Inter-comparison Project 3 (CMIP3). The present study is heavily influenced by the two new data sources at our disposal. Firstly, we have spoken directly with the people in northeast Bangladesh. Their stories tell us that not only is the monsoon rainfall important, but also the pre-monsoon or summer rainfall between March-May. Secondly, we have access to regional climate model output initiated using the results from the Coupled Model Inter-comparison Project 5 (CMIP5). These sources of information enable us to update previous projections for northeast Bangladesh and to tailor the analysis to the people's expectations.

## 12

# How art and climate research can collaborate in a community based project

*Zakia Naznin and Mathew Stiller-Reeve*

This presentation will tell the story of how an artist contributed to a climate research project, based in the northeast region of Bangladesh. The overall project was based around having a dialogue with the local people -including among others scientists, farmers and teachers- about weather and climate. We had workshops bringing these people together, where we discussed what constitutes high quality climate knowledge. For this to work, everyone involved needs to be open to different perspectives, not least different values and ways of knowing. We engaged an artist to be part of these discussions.

Before the project begun, the artist confessed that he was truly inspired to be a part of the collaboration. In this presentation, we will presents the artists final work and recount how his participation in the workshops inspired its development. We will then explain how it went when the artist presented his art back to the community. What did they feel about the artwork? Did the art project help to create a community feeling amongst the local people involved? This community atmosphere was an important issue since many of the participants were also about to embark on a yearlong citizens science project.

We will review the benefits and challenges faced during this collaborative art project. Most importantly, for this collaboration to work well, the artist needs to be willing to be involved. This art-science collaboration will fail if the artist is not immersed in the dialogue or if the scientists continue to talk jargon.

## 14

# Investigating the potential of applying theories on rebound effects and mechanisms in climate change adaptation and mitigation research

*Carlo Aall*

Little attention has been given to the rebound effects within climate change mitigation and adaptation literature. Still, a growing attention has been given to the need of avoiding mal-mitigation and mal-adaptation to take place, and to integrate in a more systematic way adaptation and mitigation policies in order to foster positive and avoid negative feedback mechanisms to take place between the two. This paper investigates the potential of applying theories of rebound effects on the climate change mitigation and adaptation discourse in order to gain a better understanding of the following processes: The effectiveness of climate change mitigation and adaptation measures, and the feedback mechanisms between the two. In doing so the paper presents a model for identifying rebound effects taking place within and between the two policy domains of climate policy. The model differentiates between three main categories of rebound effects: (1) Intra rebound effects: The situation in which net GHG reduction is lower than anticipated, or the net effect of climate change adaptation is lower than anticipated. (2) Inter rebound effects: The situation in which climate change mitigation efforts increases climate change vulnerabilities, or climate change adaptation increases GHG emissions. (3) Cross rebound effects: The situation in which intra and inter rebound effects takes place at the same time. The paper will give examples from the tourism sector of these three rebound effects. Installing artificial snow-making facilities in relation to winter tourism can produce intra rebound effects in the way that the ski resort will become more dependent on an abundant supply of fresh water in order to produce snow. Examples of inter rebound effects in winter tourism are even more profound. Here we may identify a 'ladder' of climate change adaptation ranging from adjustments to transformative efforts: Installation of artificial snow making facilities at existing ski resorts; extension of existing ski slopes to higher altitudes; supplementation of existing ski resorts with new and more snow reliable ski resorts within the same ski destination; establishment of new ski destinations in more snow reliable areas; construction of outdoor artificial (mostly snowflex) or hybrid (artificial + natural snow) ski slopes; construction of 'roofs' over natural ski slopes making them a semi-indoor arena; and construction of a 100 % indoor skiing arenas with 100 % controlled climate conditions. In all of these examples, although to a varying degree, we might experience inter rebound effects in the form of increased energy-use and accompanying GHG emissions from constructing, maintaining and running of the different installations. The paper will conclude by discussing ways to mitigate inter, intra and cross rebound effects, and also discussing future research needs.

## Planning for climate change vulnerability?

*Carlo Aall, Halvor Dannevig, Kyrre Groven and Marta Baltruszewicz*

Adapting society to challenges posed by weather related natural hazard events (WNHE) has always been a central issue of spatial planning (Burby and Dalton, 1994; Burby, 1998) - although the extent of such planning actually taking place and being effective in mitigating disaster events is often dubious (Burby, 2005). The history of spatial planning as a policy means for local adaptation to climate change is however relatively short (cf. Davoudi, Crawford, Mehmood, 2009; Wilson and Piper, 2010), and research on constraints experienced by local authorities in this respect has revealed rather simplistic factors, such as limited resources, lack of relevant competence and lack of information (Measham et al, 2011). In this paper we will pursue the points made by Measham et al (2011) that this focus has obscured a wider set of constraints which need to be acknowledged and addressed if adaptation is likely to advance through municipal planning. Thus we will lean on insights from previous research on local spatial planning and environmental planning prior to the climate change adaptation debate arose (e.g. Næss, 1994; Næss and Sagli, 2000), as well as the perspective of 'risk society' outlined by Ulrich Beck (1996) later expanded on and specifically applied to the climate change discourse by Karl G Høyer (2010), and use these insights to analyse experiences from recent WNHEs events taking place in Norway in order to shed light on the problems and prospects of adapting to climate change by means of spatial planning. In particular, the paper will sum up examples from three recently finished research projects: (1) A three-year project analyzing 10 former and 4 ongoing land-use planning processes in which severe natural hazard events or risks have taken place or been identified in the region of Western Norway. (2) A one-year project comparing repair costs and costs of reinforcement and proactive measures for 13 cases of WNHE affecting different categories of physical infrastructure in Norway. (3) A one-year project analyzing the so-called October flood of 2014 in Hordaland and Sogn og Fjordane in order to assess to what extent the observed damage could have been avoided if planning had been done in a better way. The two main conclusions from these three projects are: (1) Even if the issue of climate change adaptation has been on the local policy agenda for more than 10 years in Norway, so far no municipalities in Norway have given priority to produce a designated climate change adaptation plan. (2) Even though it is very clear, by analyzing historic natural hazard events, that it in most cases are socioeconomically profitable to conduct reinforcement and proactive measures on public physical measures, the most frequent adaptation strategy is that of being 'reactive' and thus to carry out adaptive measures 'post-incident'. This means to wait until damage occurs and then take the cost of repair and not reflecting on risks relating to climate change, and (thus) merely reverse the infrastructure to its original. The reasons for these situation are found to be: (1) An ongoing reduction in budgets for maintenance of physical infrastructure. (2) An ongoing reduction in the administrative capacity for spatial planning and local environmental policy. (3) A limited political willingness to take into consideration natural hazard risks and climate change vulnerabilities. (4) Neither current insurance arrangements nor current government schemes for compensation of natural hazard damage costs have incentives for prioritizing proactive measures.

## 16

# The roles of private actors in urban climate change adaptation – emerging patterns of public-private cooperation

*Johannes Klein and Sirkkü Juhola*

International and national policy documents as well as research call for a stronger involvement of citizens and the private-sector in climate change adaptation. It is, however, yet unclear, what type of public-private relation is envisaged and how these public-private cooperation modes could be applicable across state concepts and administrative traditions that are significantly different. This study uses examples from two urban administrations (New York City and Helsinki) from two different political traditions to explore how private action and public-private interaction in urban climate change adaptation has emerged. We analyse how approaches to governance and administrative traditions shape the emergence of partnerships for adaptation and explore the limits to answering the call for more private responsibility for adaptation in the urban context. Our findings indicate that New York City's and Helsinki's approaches to climate change adaptation both strive for an inclusion of citizens and the private sector, but at the same time they are strongly influenced by the respective administrative systems and approaches to governance. This means that changes in governance approaches and public administration can be observed but the trajectories of these changes are fundamentally different. Thus, the results show that it is unlikely that there is an easy way of transferring successful public-private adaptation actions across administrative traditions and any such actions should be carefully scrutinized with respect to the suitability and legitimacy of the procedure and potential unintended outcomes, and they do not necessarily lead to improved action on adaptation.

## A modeling perspective on the personalized climate service

*Igor Esau, Sergej Zilitinkevich and Alexander Baklanov*

Growing capacity and accessibility of high-performance computing open qualitatively new perspectives on personalization of climate services. The personalized climate service is essentially and necessarily a set of technological instruments (models, knowledge databases as well as automated web interfaces to them), which minimize the need for an educated professional middleman in providing targeted climate service. Here, we avoid a general discussion but illustrate the idea with statistical-dynamical extreme weather downscaling for the local wind climate assessment. It is recognized now that turbulence-resolving (e.g. large-eddy simulation) models robustly reproduce the turbulent flow over realistic complex topographic features. We utilized the Parallelized Atmospheric Large-eddy Model (PALM) to simulate the extreme wind regimes over Bergen, Norway. The PALM horizontal resolution was 25 m and the vertical resolution was 10 m. The simulation results were compared with the available wind and gustiness measurements in the area. The results demonstrate that the near-surface winds are strongly stirred by the topographic features, and hence, the simulated wind map reliably represent the spatial variations of the wind characteristics. This high-resolution map reveals the areas (or geographical 'hot spots') where the extreme winds are re-enforced or attenuated by the relief for each of the cardinal wind directions forecasted by the synoptic-scale numerical weather prediction systems. We consider in details the impact of the observed and expected storms on the infrastructural 'hot spots' (Sotra and Askoy bridges) in Bergen where high quality observational data is also available.

The presented extreme wind assessment shows that the turbulence-resolving models are sufficiently matured to contribute to high-resolution extreme wind standard methodology. Once calculated and verified for a given territory, the assessment maps could be used with almost no additional cost to improve preparedness at the societal scales down to individual households and for different climate change scenarios. Further reading could be found in the following publications.

Baklanov A. et al., 2011: The Nature, Theory, and Modeling of Atmospheric Planetary Boundary Layers Bulletin of the American Meteorological Society, 123-128

Esau I. et al., 2012: Micro-climate on Mega-computers, META, 1, 13-17

Outten S. and Esau I., 2013: Extreme winds over Europe in the ENSEMBLES regional climate models Atmospheric Chemistry and Physics, 13, 5163-5172

Zilitinkevich S. et al., 2015: Megacities - Refining Models to Client Environment, Bulletin WMO, 64(1), 20-22

Zilitinkevich S. et al, 2016: Monitoring and forecasting of personal environment, Fundamental and applied hydrophysics, 9(1), 93-97



## The impact from changing inflow of warm Atlantic water into the Arctic Ocean on the sea-air exchange of carbon dioxide and methane in the Laptev Sea

*Iréne Wåhlström, Christian Dieterich, Per Pemberton and H.E.Markus Meier*

The Laptev Sea, one of the shallow shelf seas in the Siberian Arctic, is generally a sink for atmospheric carbon dioxide and a source of methane to the atmosphere. We investigated how sensitive the net sea-air exchange of carbon dioxide and methane is to observed changes in the inflow of Atlantic water into the Arctic Ocean occurring after 1990. In addition, the atmospheric conditions are examined. Both physical and biogeochemical effects are investigated in a series of sensitivity experiments by utilizing a time-dependent coupled physical-biogeochemical column model. The forcing are kept climatological over the analyzed 40 years except one, which is compared over two periods, 1970-1989 and 1991-2009.

Our results indicate that the net sea-air exchange of carbon dioxide is more sensitive to the increased Atlantic water inflow than the flux of methane. The increased volume transport of water in the Atlantic layer increases the ocean net uptake of carbon dioxide more than the warming of the incoming bottom water as the vertical advection is enhanced in the first case. However, the methane cycling is mainly affected by temperature increase, regardless if the warming originates from the atmosphere or the incoming bottom water, causing increased outgassing to the atmosphere.

In summary, our results suggest that the observed changes in the Atlantic layer and the atmosphere potentially had a substantial impact on carbon dioxide uptake from the atmosphere in the Laptev Sea. However, the results suggest that the Atlantic layer impact on the outgassing of methane is less important.

## Farmers' attitude towards risk and the scope for insurance as private adaptation to future extreme climate

*Doan Nainggolan, Marianne Zandersen and Mette Termansen*

The latest IPCC report has highlighted among other things that the frequency and magnitude of climate extreme events are increasing. For the Nordic countries, extreme precipitation is of particular relevance and agriculture is one of the key economic sectors which will be significantly affected. Research to inform effective farm adaptation to extreme climate is urgently needed. The paper aims to 1) assess farmers' perception of risk in general and in relation to future extreme climate and 2) to model to what extent different farmers are likely to financially insure their agricultural activities as a potential form of adaptation to more (projected) extreme climate in the future. The analysis for the present paper draws on data collected via online survey involving a representative sample of farmers across Denmark capturing heterogeneity of farmers and diversity of agricultural land uses. 1000 respondents completed the survey. The survey consists of two components: farmers' attitude towards risk and choice experiment of insurance under more extreme climate in the future. Our preliminary analysis indicates farmers' inclination towards taking risk. Presented with three sets of predicted project outcome scenarios, the majority of the farmer respondents chose the riskier alternatives. With regards to farmers' preference for insurance, our preliminary model estimates suggest that on the one hand insurance premium and the farmer self-coverage in the event of loss significantly influence farmers' decision whether or not to take up an insurance scheme. The findings on the other hand suggest that public intervention through provision of subsidy can increase the attractiveness of agricultural insurance against extreme climate. These early findings also indicate that generally farmers tend to prefer not to insure themselves against climatic risks. All in all the findings suggest a close link between farmers' general risk taking attitude and their adaptation response to future extreme climate. The present research gives insights into the complexity of farm level decision making in response to a changing climate. Further, it sheds lights on the economics of adapting to climate change in the agricultural sector highlighting the interdependency between private and public adaptations. Equally important, the research has potentials to inform effective public intervention towards farm level adaptation decision making.

## Local-scale early warning systems for drought - can they increase community resilience?

*Lotta Andersson, Julie Wilk, Phil Graham and Jacob Wikner*

Within the DEWD project (Drought Early Warning Detection) the potential of an early warning system for drought (EWS) to increase community resilience was evaluated. A pilot study was carried out in the Limpopo river basin in South-Africa, with the aim to identify and analyse possibilities and constraints and provide recommendations for development of local drought monitoring and forecast systems. Based on input from workshops, a system was build and tested in two rural communities. The system was based on integration of modelling (meteorological seasonal forecasts linked to a hydrological model), local knowledge, and wireless sensor networks. Assessments were made with regard to the potential to facilitate the initiation of early actions by local communities, as well as of how the national and provincial level can use forecast in order to enhance proactive actions in order to reduce the negative impact of droughts.

The pilot study took place in the growing seasons of 2013/2014 (a wet year) and 2014/2015 (a dry year). Seasonal forecasts of rainfall, soil moisture and river runoff on the sub-catchment scale were compiled. Sensor network for monitoring of soil moisture and rainfall were established and a set of community workshops were arranged. Workshops were also held with extension officers, as well as on the provincial level.

The seasonal forecasts that were disseminated to the communities consisted of rainfall, soil moisture and river runoff on the sub-catchment scale. They were compiled by coupling of seasonal climatological forecasts to a hydrological model (ACRU). The use of indigenous knowledge for long- and short term predictions of climatological conditions was evaluated from a set of community meetings. During workshops, potential measures if the wetness conditions of the coming season could be foreseen were identified, as well as the actual actions carried out during the two years of the project. These two years turned out to be one unusually wet year, followed by an unusually dry year, which corresponded to the predictions from the seasonal forecasts. Also attitudes towards the potential harmful impacts of forecasts that later turned out to be wrong were assessed. Finally, the potentials and challenges of the use of community engagement in monitoring with the help of sensors, with the aim to follow the actual development of drought on the local scale were assessed. One of the main conclusions was that although the quality of the forecasts, including components as relevance, transparency and clarity are vital, such development is not enough to ensure a successful EWS. To ensure that a EWS improves community resilience, a prerequisite is improvement of the communication channels between the local and provincial level, where the present top-down reactive policies are complemented with a bottom-up proactive component that ensures both that information is reaching, is relevant, and understandable for those concerned. In addition, EWS are only useful on the local level if there are ways to act upon them, which requires both long-term actions to increase community resilience and short-term actions (e.g. subsidies) to support responses to seasonal forecasts and warnings for drought.

## Climate modeling and decision making hand in hand – the Greenlandic perspective

*Jens H. Christensen, Nathia H. Brandtberg and Martin Olesen*

In a recent joint effort, the Danish Meteorological Institute (DMI) teamed up with the Greenlandic Ministry of Nature, Environment and Justice with the aim to build the best possible robust climate scenarios for Greenland. Climate change in Greenland means much more than melting ice and challenges from enhanced seaward traffic. Greenland is a modern society with the far to well-known challenges to government, municipalities and society at large, when it comes to climate adaptation. The Greenlandic climate is in many aspects harsh and dominated by the long relatively cold winter – relatively as the most parts of southern Greenland actually has a coastal climate that is far away from the high Arctic conditions most people would assume. Likewise, summers in Greenland are mostly wonderful offering ample time for leisure in the great wilderness or in the coastal waters. Therefore, the possible effects of climate change needs to be assessed in a societal context. A very high resolution regional climate model operated by DMI allows for unprecedented representation of the complex coast lines and mountains with the dominating ice sheet and ice covered seas in the vicinity in a modelling effort of contemporary as well as future climate conditions. Results from such simulations – time slices of 20 years for present, mid-century and end of century has been provided at 5km horizontal grid spacing for the RCP4.5 and RCP8.5 scenarios in a series of reports focusing on each of the four Greenlandic municipalities. The focus has been on aspects of change that is of relevance to various targeted user communities, including agriculture. Here the reports are going to form the backbone in climate adaptation plans currently under development at governmental level.

Here we briefly present the results of the climate simulations in the view of their use for adaptation plans and offer potential additional use of this or similar approaches.

You can down load the reports here: <http://www.dmi.dk/laer-om/temaer/klima/groenlands-klima/>

## Evaluation of guidance documents for climate adaptation of the built environment in Norway

*Åshild Lappégard Hauge, Anders-Johan Almås and Cecilie Flyen*

**Introduction:** Anticipated future climate changes will lead to increased climate loads on buildings and infrastructure in Norway. To prevent damages, and prepare the society for the changes, numerous guidance documents have been developed the recent years.

**Objectives:** The objective of this study is to give an overview of existing guidance material for climate adaptation of the built environment. 86 guidance documents are mapped and analyzed by target groups and topics. The results are seen in relation to findings from expert interviews.

**Methods:** The findings are based on a thematic analysis of Norwegian guidance material and web sites for climate adaptation in the built environment. Further qualitative results are based on seven qualitative interviews and one group interview of experts in municipalities and public organizations with responsibility for promoting climate adaptation. The selection of guidance material was performed according to chosen principles, and limited to the research center Klima 2050-subjects (damage on infrastructure and buildings caused by water), with review from Klima 2050-partner organizations.

**Findings:** The main findings from the thematic analysis of guidelines are:

- There is a large amount of guidance material for climate adaptation of the building- and infrastructure sector. 86 guidance documents are mapped and evaluated in this study;
- A large share (70 %) of the investigated guidance documents are aiming at users on municipality level or are communicating climate adaptation on a general level;
- Only one (1 %) of the guidelines are aiming at private developers. Private developers generate 80% of regulation proposals in Norwegian municipalities. At this, there might be a need for guidance material aimed at private actors;
- Thirty-six % of the guidance documents deal with flooding or avalanches. A large amount of the documents concern measures of climate adaptation of roads. There are less guidance documents on climate adaptation of buildings and railways;
- Guidance material targeting decision processes are lacking; e.g. instructions that explain coordination between sectors, how to plan a decision process, what actors that should be part of specific meetings;
- A relatively high share of the guidance material communicates climate adaptation at a general level, focusing on background information rather than in-depth practical measures.

The main findings from the expert interviews on guidance material are:

- The interviews confirm an overwhelming amount of guidance material. This may cause confusion and uncertainty among users;

- The guidance material is not necessarily practically aligned. There is a risk that high academic level of language, terms, and configuration, are difficult to understand and employ for some users. Practical measures for climate adaptation are needed, especially in smaller municipalities with generalists rather than specialists;
- Employees in the municipalities lack time and capacity to seek and read guidance material on climate adaptation;
- Web pages on more specific subject areas seems to be more in use than general web pages for climate adaptation;
- Increased knowledge among the users would lead to a more effective use of the guidance material, and faster searches for the right documents.

This study is conducted as a basis for further case studies for Klima 2050 in municipalities and organizations, where the same subject areas will be studied from the user's perspective. Further analysis of the guidance material is needed, and should evaluate the practical versus academic text in the guidelines. The paper gives suggestions on how climate adaptation of buildings and infrastructure can, or should, be addressed and communicated in the years to come.

## Private autonomous adaptation to climatic hazards in coastal Taiwan communities

*Hung-Chih Hung and Wei-Chin Lee*

### 1. Background

The coastal region in Asia-Pacific is one of the most vulnerable and disaster-prone areas to the threats of climate change and extreme events. In coping with these threats, most of the countries (such as Taiwan) focus on planned (anticipatory) adaptation, which is a top-down and frequently combined with various land use planning, ecosystem zone regulations and hazard warning systems to frame the adaptation strategies to climate change and disaster risk. However, there is a shift towards incorporating private adaptation elements into adaptation and warning system planning to reach the most vulnerable people and to enable stakeholders' participation in channeling the process of decision-making. Local authorities are also increasing their efforts on linking the top-down planned anticipatory adaptation to the actions of community members from the bottom-up to execute selected adaptation options. This study thus aims to improve the knowledge about the households' pre-disaster preparedness and post-disaster adaptive behavior in coping with climate-related (climatic) hazards and understand their determinants. Finally, our results also provide directions for more effective approaches to warning system planning, resilience and adaptation policy.

### 2. Methods and data

Coastal households' autonomous adaptation can be reactive or anticipated. Numerous factors can influence whether people autonomously take actions to respond to climatic hazards, such as information availability, perceived risk, adaptation (respond) appraisal, self-efficacy, social capital, socio-cognitive and socioeconomic attributes. Especially, adaptive behavior is based much on the elements regarding risk information dissemination, local understanding of risk and socio-contextual variability among community members. This may cause residents' adaptive behavior to unfold as a clustered pattern across the coastal communities, rather than one that is randomly distributed. Using a case study of the northeastern coastal Taiwan communities, we create the Model of Household Adaptation to Climatic Hazards (MHACH) from existing socio-psychological knowledge. A GIS (Geographic Information System)-based spatial statistics technique and multivariate analysis are incorporated into the MHACH analysis to test the degree to which the adaptive actions are spatially autocorrelated throughout the coastal areas, and explain why clustered adaptive actions occur in specific areas. The data were collected by a questionnaire interview that was carried out face-to-face and door-to-door by surveying householders' adaptation actions and their determinants. Using stratified random sampling, 400 households who were roughly equally distributed among the study areas were selected. Finally, 362 respondents were used in the MHACH analysis with a response rate of 90%.



### 3.Results

Using a spatial statistics and spatial regression analysis, results show that both the respondents' pre-disaster preparedness and post-disaster adaptive behavior are indeed spatially autocorrelated across the study areas and certain factors contribute to the formation of localized "hot spots" of similar adaptive actions. Simply increasing public hazard risk awareness is insufficient to encourage autonomous adaptation. The key factors that influence households' adaptive actions further include perceived risk, adaptation appraisal, socioeconomic attributes, as well as the extent of their trust in risk information, interaction with neighbors and ability of access to resources. To enhance adaptive capacity, the policy line can be targeted based on the aforementioned factors that affect adaptive behavior. Identifying geographic areas where residents have similar adaptive behavior may help policy makers strategically focus disaster adaptation more on neighborhoods where initial support for the adaptation is possible. In particular, enhancing risk communication, public participation and social trust play a critical role in encouraging residents to take adaptive actions. These findings also imply that aiming planning efforts could concentrate more on improving the warning systems in specific geographic areas where clustered residents of poorer adopting adaptive actions.

## Limits and obstacles of Climate Servicing

*Hans von Storch*

The idea of climate services have been built following the idea of weather service, which traditionally is the process of informing various stakeholders about the details of the weather to come in the near future and about risks in a stationary climate. This process is mostly a one-way flow of information, with a knowledge producer on the side of meteorology, and mostly detached users. In many cases, this flow of information can be maintained by web-pages and conventional news media such as TV.

While building climate service in the tradition of weather service makes sometimes sense, it often fails to build and share useful knowledge. Major obstacles are the presence of alternative knowledge claims, and a post-normal situation. The quality of any such service is also an issue. These challenges exist also for weather servicing, but to a much smaller extent.

Alternative knowledge claims: Very roughly, knowledge claims about climate change may be differentiated in three classes - the assessment of IPCC and similar bodies, who try to determine the extent of consensus and dissents about climate change, without specifying political and economic consequences; - “skeptics”, who either find the natural a science analysis invalid or object the political conclusions drawn; - “alarmists”, who use the narrative of climate change as a tool to “improve” the world order and economy . Everybody is influenced by such positions, and most will filter information provided by climate services to make them consistent with their a-priori knowledge system. Thus, any exchange of scientific knowledge should take into account the presence of competing knowledge claims.

Post-Normality. Science is named “post-normal”, when it operates in a set-up, so that the scientific knowledge is unavoidably uncertain (such as the value of the climate sensitivity), when politico-economic decisions are urgent (to have a sizeable reduction of greenhouse gas presence in the atmosphere, emissions are needed to be significantly reduced in the very near future), societal values are in dispute (how do we value future?), and stakes are high (a policy like Klimawende is very expensive and has massive consequences for fabric of world economy). In a post-normal situation, societal actors try to employ science as a support for their agendas; the value of scientific results is more its utility and less so the quality associated with scientific methodology.

Quality: Since planners have to take the issue of regional and local climate change into account when planning for adaptation (of, say, infrastructure or urban growth) - they are in need for guard rails of possible future change. This need invites various providers of “predictions” of futures, which will give answers to the planners’ questions, which may, or may not, be rooted in solid understanding of the robustness of available formally very detailed scenarios of possible future change. Again, a competition of world views but also of prices for the service may arise.

Weather services operate with systems of certification; maybe such a system should also be established for climate servicing. Such a system would, however hardly overcome the challenges of multiple knowledge claims and of impacts of vested interests, as described in the concept of post-normality.

## Farmer Perceptions of Climate Change and Likely Responses in Danish Agriculture

*Bryndis Woods, Helle Nielsen, Anders Pedersen and Dadi Kristofersson*

Based on a survey of farmers across Denmark (1053 responses), this paper endeavors to assess how farmer perceptions of climate change and its attendant risks as well as their perceptions of barriers to adaptation affect their cognitive desire to undertake adaptive action in the Global North. We enhance the literature by building on our knowledge of farmers' responses to climate change in the Global North by determining which factors exert the most influence on stated - rather than assumed - changed behavior. Farmers are accustomed to coping with year-to-year changes in climate, but climate change is expected to accelerate the need and magnitude of farmers' adaptation. We aim to determine factors that play a role in motivating farmers to voluntarily change behavior and find that Danish farmers do not exhibit a high degree of concern about climate change impacts. Similarly to comparable studies in the Global South and behavioral research more broadly, we find that Danish farmers are more concerned about and more likely to adapt to short-term changes (e.g. price fluctuations) than they are with regard to long-term changes (e.g. temperature and rainfall changes); they would rather expand their crop portfolios than shrink them; and they would rather make small alterations than large changes to their current farming system in the face of external pressures. However, our results indicate that the link between perceived barriers to adaptation and willingness to undertake adaptive action is more nuanced than previously believed. Although our respondents perceive many barriers to adaptation, they are - nevertheless - willing to undertake adaptive responses to both positive and negative impacts of climate change. Our results also indicate that farmers are more willing to take advantage of opportunities presented by climate change than they are to protect against its dangers, which is at odds with the prevailing assumption that farmers are primarily risk-averse.

## Assessing the Impacts of Climate on Crop Choice Decisions in Denmark

*Bryndis Woods and Dadi Kristofersson*

This paper utilizes a crop choice model with Danish agricultural data from 2000 to 2010 to analyze how climate impacts Danish agriculture through farmers' crop choices and investigate the role of both climatic and non-climatic factors. Climatic factors include temperature and precipitation and non-climatic factors include farm characteristics such as land-use portfolio, size, input and output prices. Variables that are not observable to the modeler but are a factor in farmers' crop choices are considered, for example, characteristics of the farm. The model is consistent with the complexity of crop choice decisions, most importantly, crop rotations. We estimate how climate has affected crop choice in the period 2000-2010 using Danish land allocation data. We enhance the literature by building on our knowledge of farmers' responses to climate change in the Global North by determining which factors exert the most influence on land-use allocations. Our results verify that crop rotational patterns are extremely important to take into consideration when assessing farmers' land allocation. Results also show that land allocation in Denmark is shifting away from staple cereals and towards maize and grassland and that there is a strong correlation between crop choice and climatic factors.

## How can a research centre facilitate innovations for climate adaptation of buildings and infrastructure?

*Anders-Johan Almås, Berit Time, Lena Bygballe and Kim Robert Lisø*

SFI Klima 2050, a Centre for Research-based Innovation, will reduce the societal risks associated with climate changes and enhanced precipitation and flood water exposure within the built environment. Emphasis will be placed on development of moisture-resilient buildings, stormwater management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision-making processes. Both extreme weather and gradual changes in the climate will be addressed.

The Centre is a focal point for innovative and multi-disciplinary research, hosting 20 different actors in research, development, innovation and implementation for climate adaptation of buildings and infrastructure. Innovations in Klima 2050 are defined as new and improved solutions, products, processes and business models that exploit technologies developed in the SFI and that provide added value for the stakeholders and for society. To promote and facilitate the innovation processes, the Centre has established a Klima 2050 Innovation Arena. The innovation arena shall develop innovation actions and working methods based on needs and ideas from the consortium.

The innovation activities will also include spin-off projects which will enhance cooperation with market players along the entire value chain within the Norwegian BCT sector; public authorities, manufacturers, contractors, housing manufacturers, consulting engineers, architects, project developers, planners, designers, insurance and clients.

This paper discusses how such an innovation arena can facilitate innovation for climate adaptation of the built environment, and draws on a combination of innovation theory and experiences from previous research projects to outline a framework for an innovation arena for the centre. Key issues are aim and strategy and organization and processes facilitating innovations.

## Moving the Bangladesh Meteorological Department from climate data to climate information

*Mossammat Ayesha Khatun, Md. Bazlur Rashid and Hans Olav Hygen*

Bangladesh is one of the most vulnerable developing countries in the world to suffer from various natural disasters such as flood, cyclone, earthquake, landslide and tsunami. This has a devastating impact on human life, economy, and environment. The ongoing economic development can be seriously hampered if the threats from natural disasters are not mitigated in an appropriate manner. The Government of Bangladesh through its nodal agencies, such as the Bangladesh Meteorological Department (BMD), is therefore giving high priority to reducing the impact of natural hazards in the country.

The Norwegian Ministry of Foreign Affairs has a strong presence in Bangladesh and is actively supporting several projects. One is this project between the Bangladesh Meteorological Department (BMD) and the Norwegian Meteorological Institute, and called: "Institutional support and capacity building for mitigation of weather and climate hazards in Bangladesh".

The main goal of this project is to reduce the impact from natural hazards in Bangladesh by increasing the capacity of BMD through a joint institutional cooperation project structured in four tasks:

1. Public Weather Services including training of BMD operational weather forecasters in Norway and Bangladesh
2. Climate Services including training in climate analyses and empirical – statistical down-scaling of climate predictions from global models
3. Contribution to planning for long term improvement of weather and climate analysis and prediction systems
4. Project management and mutual project planning

The project has been running since 2012, where the activities has been focused around two workshops a year, one in Bangladesh and Norway. Task 2 Climate Services delivered this spring a climate report produced by BMD, launched may 31st. The report analyses data from all 35 weatherstations run by BMD, and presents the normals and summaries of the historic weather and climate of Bangladesh. Unlike the raw datasets, will this report be freely available on the webpages of BMD and MET Norway. The intention of the report is that it may serve as a basis for further climate knowledge and climate adaptation in Bangladesh.

## Future Projections of Extreme Winds for Norwegian Infrastructure Planning

*Stephen Outten*

Extreme winds cause vast amounts of damage every year and represent a major concern for numerous industries including construction, insurance, afforestation, wind energy and many others. A critical component of climate change adaptation is to improve our understanding of extreme events and to estimate how their frequency and magnitude are likely to vary in the future. Accurate projections of these changes will be invaluable to decision makers and to society as a whole.

A case study highlighting the assessment of future changes in extreme winds for the construction of the Hardanger Bridge in Norway is presented here. Such large-scale construction projects often require an assessment of extreme winds, which is based only upon the historical observations of wind, when the climate was approximately stationary. Under a changing climate, infrastructure built to last for the next fifty years or more may experience events not seen in the observational period.

Extreme winds were estimated for four downscalings from the ENSEMBLES project - the DMI and SMHI downscalings of both the Bergen Climate Model and the ECHAM5/MPI-OM coupled GCM. This was done using a peaks-over-threshold approach and the Generalized Pareto Distribution (GPD) to obtain the projected change in the 50-year return wind, along with the associated uncertainties. A novel method was developed to combined this model estimates with observations to create a new set of estimates applicable to the design and construction of infrastructure. Given the close collaboration with the engineers involved in the bridge's construction, the method was tailored to fit with existing practices and standards. The results and methodology will be presented; along with the current work to develop this methodology into a simple climate service will also be discussed.



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# Urban adaptation to climate change in Europe – transforming cities in a changing climate

*Birgit Georgi*

Climate-resilient cities matter for a resilient Europe, but they are increasingly challenged with climate change impacts such as prolonged heat waves, flooding, extreme precipitation or extended drought periods. These issues are intertwined with socio-economic factors like demographic structure, work patterns, income levels or lifestyle, which are also undergoing change. This relationship reveals the systemic nature of climate change impacts and raises questions about conventional solutions to problems. A long term, systemic approach not only offers solutions for adaptation, but boosts city transformation overall, creating resilient and highly attractive places for people and businesses.

The recent report of the European Environment Agency on the subject (due at 5 July 2016) describes the action taken over the last couple of years by numerous local, regional and national governments and the EU to adapt cities to climate change. It reflects this action against the need for a systemic approach to address the challenges ahead and draws conclusions on necessary action that the different stakeholders need to develop and implement.

## Bilateral collaboration between Norway and Cuba: From research to informed climate change adaptation measures for food security

*Juan-Carlos Antuna-Marrero, Michel D S Mesquita, Alan Robock and Odd Helge Otterå*

Adapting to climate change comes at a cost: proper and continuous research measures are needed to provide informed decisions. The Bjerknes Centre for Climate Research and international partners have played an important role in empowering climate scientists in Cuba with opportunities to exchange knowledge, to build computing capacity, and to create climate products that are relevant for robust preparedness to climate extremes and food security.

This bilateral cooperation between Norway and Cuba has been successful, as illustrated by the XCUBE project, which focused on extreme events, such as hurricanes, drought, and changes in sea surface conditions in the Caribbean. For instance, one of the work packages, which focused on an assessment of the sea surface temperature trends in observations and models for the Caribbean and the Antilles, show a statistically significant change point defining two subperiods 1906-1969 and 1972-2005. In the Caribbean, the trends are positive and statistically significant for both sub periods with magnitudes of 1.08 and 1.18 °C per century, respectively; whereas for the Antilles, the most populated area in the Caribbean, the trends are 1.32 and 1.41 °C. XCUBE also provided capacity building. We created oriented workshops in Havana in 2013 and in Camagüey in 2014, which focused on teaching about geoengineering, climatic effects of volcanic eruption, seasonal forecasting, multidecadal climate variability, Bayesian data analysis applied to climate research, reanalysis principles and applications, regional climate modeling using the Weather Research and Forecasting model, and applications of satellite information to agro meteorology. Lecturers included scientists from Norway, the United States, and Brazil.

XCUBE has contributed with results that are relevant for preparing for climate extremes, but it also paved the way for identifying a major topic for concern in Cuba: food security. In fact, the World Food Programme estimates that Cuba imports 70 to 80 percent of its domestic food - so, not adapting to changes in climate could worsen the situation, especially considering the threat of major drought events and desertification. A previous study conducted in Camaguey province shows that temperature increase could induce livestock heat stress; and the more frequent and intense droughts, could lead to water stress for pasture and livestock. A set of adaptation and mitigation measures has been proposed and some have been implemented. The most notorious ones are: a) adapting the feed management to optimal comfort conditions for cattle and pigs; b) building and maintaining adequate water reservoirs for cattle supply; and c) improving the pasture management through the use of silage, pasture spelling, and rotation.

In spite of XCUBE's success, capacity building projects need to go beyond a one-time-good-will action: it needs to be a continuous process. This creates a sense of progression and it gives scientists the time and means to follow up a project's progress into creating and implementing adaptation measures. XCUBE has already submitted a new proposal to the Norwegian Ministry of Foreign Affairs with a focus on food security, so as to extend the existing adaptation measures. One of the questions we want to answer is whether crop diversification could help reduce Cuba's needs to import food.

The Norwegian Ministry of Foreign Affairs financed the XCUBE project phase I in cooperation with the Norwegian Directorate for Civil Protection. Now that capacity building is in place and if the new funding is granted, XCUBE phase II would provide continuity to understanding the impacts of climate change in Cuba and it would give us new opportunities to collaborate closely with decision makers to help them design a more robust food security adaptation plan.

## Production and use of regional climate scenarios at SMHI - a Swedish perspective of building climate services

*Erik Kjellström, Lars Barring, Grigory Nikulin, Carin Nilsson and Gustav Strandberg*

The Rosby Centre regional climate model RCA4 has been used to dynamically downscale ten different coupled atmosphere ocean general circulation models (AOGCMs) from the CMIP5 project with horizontal resolution varying from about 1° to 3°. For Europe downscaling has been done at 0.44° (c. 50 km) and at 0.11°, (c. 12.5 km). In addition, RCA4 has also been used to dynamically downscale ERA-Interim reanalysis data as part of the model evaluation process. Results from the RCA4 EURO-CORDEX simulations has been analysed for model performance, added value of high resolution and various features of climate change. Particularly, a dialogue with Swedish end users has resulted in analysis of a number of climate variables and indices that are reported upon in this study. Examples are given of how information from the climate change experiments is used in a national climate service perspective which includes dissemination through the SMHI web page.

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## Non-stationary extreme value analysis for precipitation over Norway

*Stephanie Mayer, Asgeir Sorteberg and Anita Verpe Dyrødal*

So far values for current infrastructure design have been calculated under the assumption of a stationary climate, meaning extreme events will not vary significantly over time. However, climate change may modify the intensities, durations and/or frequencies of climatic extremes over time (e.g. D. Jakob, 2013). Thus, the stationary assumption is becoming invalid and may therefore lead to flawed design values.

As proposed by Cheng and AghaKouchak, 2014, design values may have to be recalculated under the assumption of non-stationarity of the climate due to climate variability and climate change.

We will present preliminary results from the ongoing NFR-supported project 'ExPrecFlood-Climatic changes in short-duration extreme precipitation and rapid onset flooding - Implications for design values'. We will apply the Non-stationary Extreme Value Analysis (NEVA) to observed precipitation extremes at a few single locations in Norway. Further, we will apply NEVA for projected precipitation extremes in Norway under a future emission scenario. As data pool we will use an ensemble of high-resolution regional climate models within the Euro-CORDEX initiative.

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## The development of Climate Services; case: The Norwegian Centre for Climate Services (NCCS)

*Inger Hanssen-Bauer, Hege Hisdal and Stephanie Mayer*

The notion of what climate service involves, which climate services the community needs, and the roles (if any) national climate service centres should have, varies between countries. Thus, there is a great variety in how climate services have been built. In Norway, the Norwegian Centre for Climate Services was established as a collaboration between three institutions. In this presentation, we will provide an overview of the development of NCCS, what we see as our main tasks, who we see as our main customers, and where we think the border should be between public and private services. We will discuss the weak and strong aspects of the Norwegian solution on the Climate Service issue based on our experiences, and we will share our visions for the further development of the Norwegian Centre for Climate Services.

## Framing as social uncertainty in building urban climate resilience

*Arjan Wardekker*

Building urban resilience to climate change and other challenges will be essential for maintaining thriving cities into the future. Resilience has become very popular in both research on and practice of climate adaptation. However, people have different interpretations of what it means: what resilience-building contributes to, what the problems, causes and solutions are, and what trade-offs, side-effects and other normative choices are acceptable. These different ways of 'framing' climate resilience are hidden in the positive, but sometimes fairly vague, language used to promote it.

Based on the current urban resilience literature, I will describe divergent ways of framing resilient urban climate adaptation and will explore their implications. Two important frames of urban resilience include the 'system resilience' frame, which focuses on maintaining urban functions and processes, and the 'community resilience' frame, which emphasises urban life, and community capacity & self-sufficiency. Other important (contrasting) frames include 'static resilience', dealing with quick return to equilibrium, and 'dynamic resilience', dealing with adaptability and co-evolving with trends.

The frames used by scientists, policymakers, and stakeholders reflect social uncertainties in climate adaptation, related to values, preferences, and goals. They entail different visions on the urban future, leading to different potential realisations of climate change adaptation. Leaving them implicit can result in a 'dialogue of the deaf', potentially leading to adaptation failure.

Urban decision-makers and stakeholders will need to investigate and develop a clear vision on what they mean by urban resilience: what are the goals, and who's or what's resilience are we talking about? Explicit exploration of the current and potential frames will help to cultivate meaningful discussion on the choices and trade-offs to be made in developing climate-resilient urban futures.

## Investigating the potential of SST assimilation for ocean state estimation and climate prediction

*Francois Counillon, Noel Keenlyside and Ingo Bethke*

The Norwegian Climate Prediction Model (NorCPM) assimilates the stochastic HadISST2 product with the ensemble Kalman Filter data assimilation method into the ocean part the Norwegian Earth System model. We document a pilot stochastic reanalysis for the period 1950-2010 and use it to perform seasonal-to-decadal (s2d) predictions. The accuracy, reliability and drift is investigated using both assimilated and independent observations. NorCPM is found slightly over-dispersive against assimilated observations but shows stable performance through the analysis period ( $\sim 0.4K$ ). It demonstrates skill against independent measurements: SSH, heat and salt content, in particular in the ENSO, the North Pacific, the North Atlantic subpolar gyre (SPG) regions and the Nordic Seas. Furthermore, NorCPM provides a reliable monitoring of the SPG index and represents the variability of the temperature vertical structure there in good agreement with observations. The monitoring of the Atlantic meridional overturning circulation is also encouraging. The benefit of using flow dependent assimilation method and constructing the covariance in isopycnal coordinate are investigated in the SPG region. Isopycnal coordinate discretisation is found to better captures the vertical structure than standard depth-coordinate discretisation, which can deepen the influence of assimilation when assimilating surface observations. The vertical covariance shows a pronounced seasonal and decadal variability, which highlights the benefit of flow dependent data assimilation method. This study demonstrates the potential of NorCPM for providing a long reanalysis for the 19-20 century when SST observations are available. The results of s2d predictions carried out will be presented, and the potential to use this method to assess decadal predictability over the historical period will be discussed.

## Measuring adaptation?

*Anna Bohman and Lotta Andersson*

Since a few years back measures are being taken and strategies and plans are being implemented in the name of climate adaptation. In many countries institutional structures as for how to deal with this fairly new policy area are in the making and roles and responsibilities are about to settle.

So far less attention has been paid to measure and follow up the effects of the work that has been done so far. This is partly due to the lack of methods and indicators whereby adaptation can be evaluated.

Evaluating adaptation is tricky due to its multidimensional and integrated character, loosely defined boundaries (i.e. what is considered as adaptation) and long time horizons. Moreover the definition of progress related to process and outcome, is adding complexity to the creation of indicators.

This presentation reports from a governmental mission aiming to develop a method for evaluating climate adaptation activities in Sweden. Challenges related to scale, scope and the measuring of effects are being discussed and problematized.



## Identification and Application of Surrogate Models for Urban Drainage Modelling

*Cecilie Thryssøe, Morten Borup and Karsten Arnbjerg-Nielsen*

Future projections of climate change show an increase in severe intensity rainfall events and their frequency. This change in precipitation pattern coupled with rapid urbanization is expected to increasingly overburden the urban storm- and wastewater systems. If no action is taken, it will lead to an increased risk of pluvial flooding and combined sewer overflows.

To increase the resilience of the urban storm- and wastewater systems, models are applied to predict the surcharges and discharges from the drainage systems. State-of-the-art modelling tools are high-fidelity distributed physically based models. However, such models include much more details than needed for most purposes and require small time steps to avoid instabilities; leading to high computational demands. Thus there is a need for faster models for planning and real-time control purposes, where multiple fast simulations are required. This project focuses on derivation and use of cheaper-to-run surrogate models that can substitute the high-fidelity models by mimicking the dynamics of these models sufficiently well.

This project presents the results and experiences gained from setting up a surrogate model for a hydraulically complicated catchment where both sea surges and extreme precipitation leads to substantial flooding. The catchment is approximately 42 km<sup>2</sup> and located by the sea. The downstream part of the catchment is heavily affected by flooding. A conceptual MIKE URBAN model of the area is set up and used for training and validating the surrogate model.

The surrogate model consists of compartments, which are delineated areas of the urban drainage system. In each compartment the volume of water is modelled from a mass balance of the input and output discharges. The discharges between the compartments are trained from the discharges from a high-fidelity model. The identified steps in surrogate modelling are: (i) Division of the drainage system into compartments, (ii) Creation of training data from a high-fidelity model, (iii) Training of the surrogate model, (iv) Definition of indicators for evaluating the surrogate model, and (v) Validation of the surrogate model.

A key element of identifying the appropriate surrogate model is to capture the different hydraulic phenomena with the simplest possible model. A simple model setup can be applied in areas with an unambiguous relationship between storage and water level, whereas more focus is needed in areas with an ambiguous relationship. The identification of such areas is thus a key part of surrogate modelling. Training data is created from the high-fidelity model to set up the surrogate model. Indicators for evaluating the model performance are determined and evaluated based on the intended use of the surrogate models. Finally the performance of the surrogate models can be evaluated by comparing them to the high-fidelity models applying different rain events.

Preliminary results indicate that the surrogate models are able to emulate the discharges and volumes of the high-fidelity model well, while using only a fraction of the computational time.

## Environmental impacts of flood control measures in climate change adaptation strategies

*Sarah Brudler, Karsten Arnbjerg-Nielsen, Michael Zwicky Hauschildt and Martin Rygaard*

Because of climatic changes, large investments are needed to keep flood risk at an acceptable level in urban areas. Increasing dimensions of underground sewer systems and retention basins are increasingly supplemented with multi-functional approaches, aimed at managing water locally and/or route it on the surface without harming assets. When evaluating different adaptation approaches, a cost assessment is typically carried out, while environmental impacts usually are not considered. To close this gap, a Life Cycle Assessment (LCA) based method is developed, which allows to quantify environmental impacts of different storm water management strategies. It is tested with two different adaptation strategies for the Nørrebro catchment in Copenhagen, Denmark: A Cloudburst Management Plan (CMP), which uses a multi-functional approach and combines green infrastructure with subsurface pipes, and a Subsurface scenario (SSA), which uses only pipes and underground retention basins. To ensure comparability, flood safety levels for different rain events are defined, which have to be met in both scenarios. The environmental impacts are calculated for eight different categories, including climate change, resource depletion, eutrophication and acidification. The case study shows significantly lower impacts for the multi-functional, green infrastructure CMP, compared to the SSA. Among the installations, those measures which are installed to ensure no water on the surface during rain events with a return period of 10 years and handling small events with a return period of up to 0.2 years cause by far the largest share of the total environmental impacts in both scenarios (up to 96% for the CMP, and up to 84% for the SSA. In contrast, measures aimed at handling extreme events with a return period of up to 100 years only contribute up to 4% of the environmental impacts for the CMP and less than 1% for the SSA. Our method helps explain how the handling of everyday events and extreme rain events affect the environmental sustainability of climate change adaptation and it enables cities to consider the environmental sustainability of climate change adaptation solutions in the planning process.

## Big Data facilitating climate change adaptation on the coast

*Alexander Rumson, Simon Jude and Stephen Hallett*

The coast is a volatile region in which mounting pressures are arising through a combination of dynamic natural hazards and rapidly increasing human usage. This results in the generation of high levels of risk. Climate Change hazards exacerbate coastal vulnerability, placing increasing pressure on governments and society to implement adaptive measures. To make informed choices coastal managers require access to the large volumes of data relating to coastal processes and human activity. In the UK, such data is held by many different organisations and historically, has been caught in information silos. Yet this vast array of information needs to be collated, combined and analysed to reveal interactions, climate change impacts and the likely success of adaptation measures. A research project is currently being undertaken at Cranfield University, UK, which seeks to address these real issues. This research focuses on how Big Data technologies can be utilised to enable large volumes and varieties of coastal data to be combined, enabling wider trends to be established, act as an early warning system and provide an evidence-base for decision makers. The project is sponsored by the UK funding council NERC, with support from district level government and the British Geological Survey. It is also part of a wider collaboration between government and academia. The project is being undertaken within the DREAM 'Centre for Doctoral Training', which focuses on the application of Big Data techniques to environmental risk adaptation. The research further builds on past projects such as the Tyndall Centre and iCoast. In this presentation, the ongoing research and initial findings will be presented; this will include an overview of the core issues the research is addressing, Climate related challenges coastal managers face, data sources that are being utilised, and examples of how this data is being combined and analysed.

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# Services for climate change adaptation in Sweden -Production and communication of county-based climate indices

*Elin Sjökvist, Jenny Axén-Mårtensson and Gunn Persson*

As a result of frequent communication between SMHI and stakeholders, especially the County Administrative Boards, requests were raised on having RCP-scenarios downscaled to finer resolution. The main reason was the need for hydrological studies, which demands a downscaling technique correcting systematic deviations from observed data.

In 2014 regionally (RCA4) downscaled CORDEX-data for Sweden was refined to 4x4 km<sup>2</sup> by the Distribution Based Scaling (DBS) method. The data was used for hydrological modelling and statistical meteorological as well as hydrological analyses were made. A database was formed and made available on the web, together with a technical report, metadata and instructions.

As a consequence, in 2015 SMHI was commissioned to present analyses for the 21 Swedish Counties, based on the DBS-downscaled data. In dialogue with the County Administrative Boards a list of requested climate indices and content of the reports were decided on. Results are available at the SMHI web and in the form of maps for Sweden and the 21 Counties separately. A total of 23 climate indices are presented based on temperature, precipitation and hydrological modelling data. Reports for each County, including both maps and diagrams, are also available. Additionally GIS-layers are accessible as well as general information about the material.

Currently, in 2016, SMHI is visiting the County Administrative Boards presenting the analyses as a support to their work with climate change adaptation.

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## Providing information – enabling knowledge: Regional climate service as sustainable stakeholder dialogue

*Insa Meinke*

While natural science is analyzing the sensitivity of complex systems to natural and human influences an additional infrastructure is needed to enable knowledge as basis for decision making processes. Agriculture, tourism, energy supply and coastal defense are only some examples for weather sensitive sectors at the coasts. In these sectors climate and coastal research can serve as basis for decision processes.

However, scientific knowledge cannot be directly translated into necessary action. Peer reviewed articles with regional focus are widely scattered and scientific agreement is often not documented on regional scales. Also, the format of regional research results is often not decision relevant and public interpretation of research findings does not correspond to scientific knowledge.

Since ten years the Northern Climate Office maintains an intensive stakeholder dialogue to generate decision relevant information based on regional assessments and on coastal climate data available for Northern Germany. About once a week a dialogue event takes place, many individual requests are answered and interviews are given to the media. Also, several stakeholder workshops and expert interviews have been conducted. From these dialogue activities information demands of different stakeholder groups have been localized to develop decision relevant information products which may serve a broader group with similar information needs.

More than 1600 stakeholders from different user groups have registered for this service, so far. Each user group seems to prefer particular dialogue and communication forms. Since regional politicians are one of the smallest user groups a survey among mayors in the Southern Baltic Sea region have been conducted. The response shows that in many regions at the Southern Baltic Sea coast climate changes has only little priority. Also, the requested information of the mayors regarding climate change is often not part of the research agenda.

## High-resolution rainfall time series for future climate

*Hjalte Jomo Danielsen Sørup, Stylianos Georgiadis, Ida Bülow Gregersen and Karsten Arnbjerg-Nielsen*

Climate change is of great importance for urban water management today as the infrastructure planning horizon is often very long. Significant parts of the urban drainage systems is dimensioned using models that use rainfall time series as input which creates some challenges for considerations of climate change. In Denmark, the expectations for future climate is that different levels of extreme rainfall will change differently, and both seasonal and yearly precipitation will change significantly. We are lacking methods to make good artificial rainfall time series representing rainfall in future climate.

We present a method to perturb existing rainfall time series to reflect our expectations for future rainfall, both in terms of the different expectations to extremes and the expected opposing seasonal expectations. The method is based on a state space model and a technique to determine representative return periods on rainfall event basis across durations from 5 minutes to 12 hours. The return periods are used to classify the state of the event which in combination with an existing regional extreme rainfall model is used to determine an event specific change factor.

We have tested the method using ten long historical rainfall time series from Denmark and the official expectations to changes of the extremes combined with the most recent estimates for the seasonal and yearly changes. The method is able to generate synthetic rainfall series that describe all the changes in precipitation characteristics necessary to analyze and design the future of drainage systems.

The sensitivity of the methodology towards the absolute magnitude of the expected changes and towards the relative magnitude and direction of expectations to extremes and to seasonal changes are evaluated. The methodology is very robust to changes in the seasonal changes but the skill decreases with increased expectations to extremes.

## Trans-boundary impacts affecting Finland – developing the impact pathways approach to support adaptation planning

*Mikael Hildén, Fanny Groundstroem, Timothy Carter, Mikko Halonen, Adriaan Perrels and Hilppa Gregow*

It has been argued that the focus of climate change adaptation policies and actions is local, in contrast to climate change mitigation for which the corresponding focus is necessarily international and global. However, scholars and practitioners have increasingly come to realise that in a globalised world this is too simplified a view. The impacts of climate change can be felt in places sometimes far removed from where they occur, whilst the ways in which impacts spread are diverse and often complex. One promising approach that helps to understand and address these impacts is based on the concept of impact pathways (Benzie et al. 2013), which traces the causal links between impacts and their repercussions over geographical space. The links that cross national borders are of special interest as they raise questions about appropriate strategies for adaptation. We refer to these as trans-boundary impacts.

In this paper we apply and develop the impact pathways approach to explore trans-boundary impacts affecting Finland. The analysis has aimed at answering the following research questions:

What pathways can be identified for possible trans-boundary impacts of climate change in Finland?

How can these pathways be characterised, and their impact dependencies classified and evaluated?

Which trans-boundary impacts are likely to be significant for Finland?

Our analysis is based on four strands of evidence: (i) an extensive collection of available statistical data that may shed light on the importance for Finland of various climate-sensitive activities, infrastructure and their dependencies occurring outside Finland; (ii) a review of literature addressing causal links between different impacts, (iii) exploratory studies with a global economic model; and (iv) interviews with Finnish and international stakeholders on trans-boundary impacts and their significance. In conducting the analysis we have explored both potentially adverse and beneficial trans-boundary impacts.

In our analysis we initially identified pathways of trade, infrastructure, finance, human mobility, biophysical effects and geopolitical processes. In the course of the analysis it became evident that a cognitive pathway through which impacts are recognized and interpreted is also significant although largely neglected, or alternatively taken for granted without reflection.

We were able to identify and evaluate the pathways using statistical data, although at this stage it is difficult to provide quantitative estimates of the trans-boundary impacts of climate change, except in specific cases such as the impacts of increasing production of renewable electricity on energy investments in Finland. In addition, exploratory, sector-based macro-economic estimates obtained through global economic model simulations, can provide indications of the order of magnitude of trans-boundary knock-on effects in comparison both to the original impacts of climate in the source region and to the direct impacts of climate in Finland itself.

Our qualitative analysis demonstrated that the awareness and recognition of trans-boundary impacts is still very mixed. The greatest awareness was found, not surprisingly, among actors who deal with issues of global and national security and with humanitarian aid. The energy sector is increasingly aware of cross-border impacts. In contrast many representatives of the private sector, with the exception of the insurance industry, appear to be less well aware of the possibilities of trans-boundary impacts. They are unlikely to have considered either the pathways affecting their operations or the potential new business opportunities that may be presented by some trans-boundary impacts. Hence, lack of recognition of such indirect impacts of climate change could itself pose significant cognitive barriers to effective adaptation at different steps along the impact chain.

We conclude that the pathways approach is useful for raising awareness of trans-boundary impacts, not least for motivating international cooperation both between countries and within sectors, and for stimulating further R&D on topics such as the modelling and management of logistics. At a practical level the dynamic nature of the trans-boundary impacts, their interaction and secondary effects and their different origins that range from temporary extreme climatic events to a gradual change in conditions, makes it difficult to draw firm conclusions on their significance for Finland. Also, in many cases it is difficult to distinguish the climate component from other, broader transboundary impacts affecting Finland. However, our findings suggest that important areas are those related to energy, food and fibre production, population, tourism and health, and as an integrating sector, education. It is also clear that Finland's future susceptibility to trans-boundary impacts of climate change will be strongly influenced by concurrent socio-economic developments. The results also imply that the regular review and updating of our understanding of this phenomenon should become a standard component of national adaptation planning.

#### Reference

Benzie, M., O. Wallgren, and M. Davis (2013). *Adaptation without borders? How understanding indirect impacts could change countries' approach to climate risks*. Stockholm: Stockholm Environment Institute.



## On model differences and skill in predicting sea surface temperature in the Nordic and Barents Seas

*Helene Reinertsen Langehaug, Daniela Matei, Tor Eldevik, Katja Lohmann and Yongqi Gao*

The Nordic Seas and the Barents Sea is the Atlantic Ocean's gateway to the Arctic Ocean, and the Gulf Stream's northern extension brings large amounts of heat into this region and modulates climate in northwestern Europe. We have investigated the predictive skill of initialized hindcast simulations performed with three state-of-the-art climate prediction models within the CMIP5-framework, focusing on sea surface temperature (SST) in the Nordic Seas and Barents Sea, but also on sea ice extent, and the subpolar North Atlantic upstream. The hindcasts are compared with observation-based SST for the period 1961-2010. All models have significant predictive skill in specific regions at certain lead times. However, among the three models there is little consistency concerning which regions that display predictive skill and at what lead times. For instance, in the eastern Nordic Seas, only one model has significant skill in predicting observed SST variability at longer lead times (7-10 years). This region is of particular promise in terms of predictability, as observed thermohaline anomalies progress from the subpolar North Atlantic to the Fram Strait within the time frame of a couple of years. In the same model, predictive skill appears to move northward along a similar route as forecast time progresses. We attribute this to the northward advection of SST anomalies, contributing to skill at longer lead times in the eastern Nordic Seas. The skill at these lead times in particular beats that of persistence forecast, again indicating the potential role of ocean circulation as a source for skill. Furthermore, we discuss possible explanations for the difference in skill among models, such as different model resolutions, initialization techniques, and model climatologies and variance.

## Observed and projected changes in floods in Norway as a basis for climate change adaptation.

*Hege Hisdal, Deborah Lawrence and Klaus Vormoor*

Adaptation to accommodate potential changes in flood hazard under a future climate should be based on a sound understanding of the likely impacts of projected changes in temperature, precipitation and other climatic variables on flood generation and of the regions and catchment types that are most vulnerable to such changes. For Norway, this is being addressed both by considering evidence for changes in observed peak flows during the past several decades using trend analysis and by estimating future changes in flood frequency using hydrological simulations based on climatological time series from EUROCORDEX RCM simulations.

Trends in over-threshold discharge events have been analysed for 211 catchments distributed across Norway over the period 1962-2012 using the Mann-Kendall test to assess changes in magnitude and Poisson regression to evaluate changes in frequency (Vormoor et al., 2016). Although the majority of the peak discharge time series considered do not exhibit statistically significant trends, trends in flood frequency are more common than trends in flood magnitude. In addition, there is a close connection between the dominant flood generating process and the sign of the trend. Catchments that show a significant increase in flood frequency are subject primarily to high flow events generated by rainfall, whereas a decrease in flood frequency is notably associated with catchments dominated by high flows generated by melting snow during spring and early summer periods. Significant changes in the timing of snowmelt-generated peak flows are all, without exception, negative, indicating an earlier snowmelt period during the past 30-50 years.

Projected future changes in flood frequency have also been analysed using an ensemble of hydrological simulations derived from 10 EUROCORDEX GCM/RCM simulations, 2 bias correction methods and 25 hydrological parameterisations for each of 115 catchments (Lawrence, 2016). Changes in the 200-year flood between a reference period, 1971-2000 and a future period, 2071-2100, is assessed using flood frequency analysis with a 2-parameter Gumbel extreme value distribution. The results indicate large regional differences in the projected changes across Norway, with median ensemble projections ranging from -44% to +56% for the daily-averaged flood magnitude. The regional differences have a close correspondence with the importance of rainfall vs. snow meltwater as the principal contributor to high flow events, but also can reflect local effects such as altitude and catchment area. The projected regional patterns of changes show a good agreement with the areas of positive vs. negative trends in peak flow frequency found in the trend analysis of observed flow timeseries.

Using these observed and projected changes as related to flood generating processes in different regions and catchment types in Norway, NVE has developed a set of recommendations for use of a climate change factor for different catchment types for six regions in Norway. Due to the large spread in the ensemble projections for individual catchments, three categories are used: 0%, 20% and 40%, rather than precise estimates. General recommendations are given for the selection of the most suitable climate factor as a function of region, catchment size, the dominant flood generating process in the current climate, and the catchment location relative to the coast. These climate factors are now used in Norway for both flood hazard mapping and for flood estimates related to the design of structures, such as bridges and dams.

### References:

Vormoor, K., Lawrence, D., Schlichting, L., Wilson, W., Wong, W.K. (2016) Evidence for changes in the magnitude and frequency of observed rainfall vs. snowmelt driven floods in Norway, *Journal of Hydrology*, 538, 33-48

Lawrence, D. (2016) Klimaendringer og fremtidige flommer (In Norwegian: Climate change and future floods). NVE Rapport (in prep.)

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## Sustainable Management and Integration of Cultural Heritage in Climate Change Adaptation

*Therese Sonehag and Marte Boro*

### Key message

Why should cultural heritage be included in climate change adaptation?

Cultural heritage contributes with identity, knowledge and resources in sustainable development and retains values that are unique and not replaceable.

By adopting measures and methods from conservation of cultural heritage and developing sustainable management, consequences of the effects of climate change may be prevented.

### Introduction

Cultural heritage means all tangible and intangible entities of significance to present and future generations. The protection of cultural heritage gives social benefits, resource efficiency and strengthens integration and resilience.

Safe-guarding the cultural heritage is a responsibility shared by everybody, acknowledged in UN global development goals (goal 11) as in the national cultural heritage codes of Norway (Kulturminneloven) and Sweden (Kulturmiljölagen).

In the message “Towards an integrated approach to cultural heritage for Europe” 2014, the EU Commission singles out climate change as one of the challenges putting cultural heritage at risk.

### What’s the problem?

Climate change and cultural heritage - what are the threats and risks?

### Needs

to reduce climate change effects (mitigation)

changing the management in a changing climate

Nordic collaboration 2010

The project “Effects of climate change on cultural heritage sites and cultural environments” was established in 2008 as a collaboration between the cultural heritage administrations of seven Nordic countries: Iceland, Greenland, the Faeroe Islands, Denmark, Sweden, Finland and Norway. The aim of the project was to assist the cultural heritage administrators in meeting the anticipated climate change and to strengthen Nordic collaboration and network building. The Nordic countries have common challenges in respect of observed and future climate change and its consequences for the management of heritage sites.

The following challenges were identified by the project:

Cross-sector collaboration

Work on legislation, regulations and standards

Developing knowledge and expertise

Information and advice

Climate and energy requirements (public and local management)

Cultural Heritage in a changing climate

The presentation, from the point of view of the national cultural heritage authorities in Norway and Sweden, is a follow-up describing work done since the project in 2010.

Europe

European standard, CEN-TC346 WG8, Guidelines for improving the energy performance of historic buildings

Adapting Northern Cultural Heritage - preparatory project within Interreg Northern Periphery and Arctic Programme 2014-2020

Sweden

National action plan for historic buildings in a changing climate

Web tool Klimatanpassning.se and the and the cross-sector network

Regional projects on analyzing cultural heritage at risk

Norway

Web tool Klimatilpasning.no

Aurland pilotproject on developing sustainable management

Monitoring project of the effects of climate change on historic buildings

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## Implementing Adaptation Plans in Danish Municipalities

*Dorthe Lund*

Climate change adaptation plans are a recent phenomenon in Danish municipalities as a first generation of adaptation plans became mandatory by the end of 2013. By the time of study the municipalities had 1,5 years to implement the plans. This paper addresses implementation in ten municipalities through interviews with municipal planners and waste water utility company employees and investigates what challenges as well as positive experiences plan implementation creates. In Denmark, climate change adaptation is mainly about managing flooding risks from. The fact that climate change adaptation is a new task and is cross sectoral creates challenges as the municipalities need to find out who in the organization are responsible and finding effective procedures for internal collaboration. From both literature and the interviews it seems that leadership focus is determining the implementation success. Furthermore, the municipalities and utility companies encounter a number of institutional barriers in particular relating to existing legislation, which are cumbersome to overcome. There is an apparent clash between the NPM logic the utility companies are subject to and the more network oriented approach the adaptation plans are suggesting. The NPM logic is apparent in the extensive requirements for documentation of cost-effectiveness, which are hard to comply with given the lack of experience with the task. On the positive side, there are very good experiences with citizen involvement as they have provided important local knowledge and in some cases have been successfully engaged in finding local solutions to flooding problems.

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# High resolutions simulations of air pollution in Bergen city

*Tobias Wolf, Lasse Pettersson and Igor Esau*

The Nansen Center in Bergen has a long competence on the application of high resolution Large Eddy Simulations (LES) for the analysis of the dynamics of the atmospheric boundary layer. This tool allows to resolve the relevant circulations over urban areas and even down to the street level giving the possibility to conduct analyses of high impact weather events like extreme winds during storms or high air pollution events during local stagnation conditions. In cooperation with the Bergen harbor authority we are currently studying the dispersion of air pollutants from oil-platform supply and cruise ships that are staying in the Bergen harbor right next to the city center. For this we are comparing the contribution of emissions from the different sources on the local pollution at the neighborhood level. Here we will present this research and suggest potential other applications of the LES technique for the planning of resilient cities.

## Understanding the societal and climatic influences of arctic sea ice loss

*Noel Keenlyside, Níels Einarsson, Astrid Ogilvie, Fumiaki Ogawa, Yongqi Gao, Torben Koenigk, Vladimir Semenov, Lingling Suo and Shuting Yang*

Understanding the major social and climatic impacts of the recent melting of arctic sea-ice is key in developing new and sustainable solutions in addressing and adapting to climate change and developing green growth. We present result on two specific issues being addressed by the NordForsk funded GREENICE project ([www.greenice.no](http://www.greenice.no)).

(1) How are small fishing communities in Iceland (Húsavík, Grímsey, Neskaupstaður) and Greenland (Ittoqqortoormiitbeing) being affected by changing sea ice conditions? Biophysical changes linked to climate impacts are closely related to small-scale fishing in the Arctic. Clearly, such activities are extremely climate and weather sensitive. Our field-work shows that fisherman are feeling such impacts directly through daily resource use, and express their concerns; for example they perceive changes in the state of the sea with confused sea conditions and bigger and breaking waves. Apparently sea ice has a calming effect on sea state, and less and receding sea ice provides a greater fetch for waves to grow in size and power. When interacting with local currents, inshore shallows, and strong winds these can easily cause conditions that prevent fishing, and also become hazardous for small-boat activities.

(2) Has the recent arctic sea-ice loss contributed to climate changes over the northern hemisphere, including in extreme weather events? Apart from sea ice other factors, such as sea surface temperature (SST) and internal atmospheric dynamics, could also have had an influence. Numerical experiments with six different state-of-the-art atmospheric models are being used to quantify the climatic contributions of the various impacts. Our preliminary results show that the observed wintertime temperature trend near the surface is poorly reproduced in our experiments using observed sea ice concentration (SIC) and SST. The impact of SIC variation seems to be confined near the surface, while SST variation seems a key for temperature trend above. This suggests a necessity to consider the atmospheric poleward energy transport associated with SST variation to understand the observed arctic amplification. We will present a quantification of the various contributions and also the sensitivity of our results to the experimental design.

## County Climate Profiles for Climate Change Adaptation

*Dagrun Vikhamar-Schuler, Eirik J. Førland, Inger Hanssen-Bauer, Hege Hisdal, Hans Olav Hygen and Irene Brox Nilsen*

Climate profiles for Norwegian counties are developed and distributed by the Norwegian Centre for Climate Services in collaboration with regional and local authorities. The profiles provide a summary of observed changes in climate and hydrology for each county, as well as expected future changes and challenges towards the end of the century 2071-2100. The climate and hydrological projections are based on the most recent global and regional climate model results. The climate profiles cover changes in temperature, precipitation, snow and wind, as well as consequences for hydrology (floods, river flow and drought), avalanches and landslides (snow, slush, quick clay, rock, earth and flood slides) and sea level rise in the specific counties.

This product aim to provide a knowledge base for climate change adaptation linked to regional and local planning in the counties and municipalities. To ensure that a useful tool is produced, the climate profiles are developed through an interactive process including a dialogue between the Norwegian Center for Climate Services and its users, particularly the regional and local authorities. Five county climate profiles were finished by June 2016, while the others will be produced consecutively. The poster illustrates the climate profile production: a dialogue integrating climate science, adaptation and planning.



## Using dense time-series of optical satellite images for glacier mapping purposes

*Solveig Havstad Winsvold, Andreas Käab and Christopher Nuth*

Glaciers are found in mountain or marine regions that are often affected by cloud cover. Currently, snow and ice are typically classified from optical satellite images using multi-spectral band ratios. The recently launched Sentinel-2A satellite and its twin Sentinel-2B (launching in end 2016), has similar characteristics as the Landsat TM/ETM+/OLI satellites. Together, these satellites will produce a tremendous quantity of medium-to-high resolution optical images worldwide suitable for glacier mapping, with increasing temporal resolution and coverage towards the more glacierized higher latitudes due to convergence of the near-polar orbits. Therefore it will be an increasingly challenging task to manually select the best annual or multiannual satellite image with preferable mapping conditions, as is the practice within the current method. Instead, the large amount of information in the dense time-series of the multiple optical sensors calls for new ways of mapping glaciers.

Our example data is based on the above-mentioned robust image ratio-method and show a seasonal variation on glaciers throughout a year, presumably because of the metamorphosis of snow. The dense time-series presented in four application scenarios, was interpreted in two ways: 1) stack statistics for each pixel, and 2) chronological interpretation of the data. First, we synthesize an optimal band-ratio image from a stack of images within one season to compensate for regional differences occurring within a single satellite scene. The second application scenario introduces robust methods to improve automatic glacier mapping by exploiting the above seasonal variation in spectral properties of snow. Typical Sentinel-2 MSI/Landsat 8 OLI high temporal resolution data was simulated using a combination of Landsat TM 5 and ETM+ 7 over a period of 4 years. Third, we explore the spatio-temporal variation of glacier surface types. Finally, we show how the synthesized band ratio images from the first application scenario can be used for automatic glacier change detection. In summary, we have explored automatic algorithms for glacier mapping applications that exploit the temporal signatures in the satellite data time-series.

## Co-production of Ocean Acidification knowledge for adaptive co-management of the coastal zone

*Halvor Dannevig, Grete K. Hovelsrud, Carlo Aall, Richard Bellerby, Philip Wallhead, Kyrre Groven, Andrew King, Evgeniy Yakushev, Marianne Karlsson, Lucy Greenhill and Jasper Kenter*

Ocean acidification (OA) in concert with climate change and other anthropogenic stressors will lead to unprecedented and profound changes in coastal ecosystems. There is little knowledge of the processes of OA in Norwegian coastal areas, about the potential consequences, to what extent OA will interact with other ecosystem stressors, and how society may respond to this situation. Sustainable management of the coastal areas therefore hinge on the ability to address and mitigate OA and OA impacts. This presentation outlines the first results from the ACIDCOAST-project, which aims to make OA a governable issue through co-production of knowledge with those who uses it for governance and industry purposes. OA and climate change add uncertainties on several levels for coastal zone management, which raises the need for better knowledge on how governance regimes can operate in an effective way given such uncertainties. Through two case studies and OA measurements and modeling in coastal areas in Sunnhordland in southern and Lofoten in northern Norway, the project will provide new knowledge about OA and OA impacts on coastal areas and develop models for how this knowledge can be used for adaptive co-management of the coastal zone. The project bring together stakeholders from industries, civil society, government organisations and natural and social scientist. The presentation will outline the project framework, as well as key issues identified in two stakeholder input workshops.

## The potential of new satellite sensors for investigating glaciers and related natural hazards

*Solveig Havstad Winsvold, Andreas Kääh, Bas Altena and Christopher Nuth*

Sentinel-2 (S2), an optical satellite sensor, features a number of characteristics that will improve mapping and monitoring of glaciers and related hazards, meaning the large swath width of 290km, the spatial resolution of 10-20m, and the repeat cycle of at least 10 days (higher towards the poles). In this study we perform a number of general tests on image radiometry and geometry as relevant to the glaciological image analysis. Based on commissioning-phase and ramp-up phase data, we find a geolocation accuracy of one pixel (at 10m) or better and co-registration accuracy between repeat scenes of around 1/3 pixel. Both error magnitudes are well acceptable for most glaciological applications. We also found patterns related to the mosaicking of the 12 detector sub-systems that form the full S2 swath. Also their magnitude will only matter in science-grade high-precision applications.

Cross-track offsets in orthoprojected LIC data due to vertical errors in the DEM used have, however, to be observed. In particular at glacier tongues, DEMs will typically be outdated due to glacier shrinkage. For some examples in the Swiss Alps we found lateral offsets in S2 images of 30-40 m over such areas. For latitudes larger than 60 degree North (i.e. north of the SRTM coverage) we found geolocation bias patterns of the same order of magnitude all over the scenes, not only over glaciers. Geolocation biases in S2-derived products would for instance affect glacier outlines, especially when compared to other data such as Landsat, because of different orbit settings and use of other DEMs in the orthorectification process. This can be avoided to a large extent for glacier velocity measurements by relying on repeat data from the relative same orbit.

Through a number of case studies, we demonstrate and evaluate the capability of new satellite sensors for glaciological applications: Automatic multispectral glacier mapping based on S2 bands 4 (red) and 11 (SWIR) turns out to be very successful, among others due to the improved resolution compared to Landsat data. This improved resolution together with the high radiometric fidelity is also important for detecting and assessing glacier lakes and their changes over time. We present an example from Harbardsbreen, a Norwegian glacier with an ice dammed lake, which has had frequent jökulhlaups the past years. From S2 data it becomes possible to track velocities of smaller glaciers and even over seasonal scales. This opens up for the possibility of obtaining both summer and annual velocities from the same sensor.

## North Atlantic and Arctic Long Term Climate Variability

*Lars H. Smedsrud, Noel Keenlyside, Nour-Eddine Omrani and Rong Zhang*

In addition to the global anthropogenically forced ongoing warming, our climate also changes from year to year because of natural processes internal to the climate system. To distinguish between the two is a challenging task of ongoing research, and the answer and partial contribution may vary from region to region. When it comes to oscillation on longer timescales (decades) the ocean probably plays an important part, and there is evidence that such long-term fluctuations are especially large in the Arctic and North Atlantic region related to the overall strength of the ocean circulation. Here we analyze some key long-term observational records that document such long-term fluctuations, and draw some important conclusions.

Society has a need for estimating “normality” as part of the ongoing adaption efforts, and historically a 30-year period between 1960 and 1990 was used as the long-term period. This has also been used as the “normality” period in Norwegian Weather forecast. For some areas this 30-year long normal period has been “updated” to 1980 - 2010 in recent years. However, examining a number of longer time series it is clear that there are large long-term fluctuations in the climate system that have periods of 50 years or more. Thus - a “normality” period of 50 - 100 years would be much more appropriate when planning future adaption. For some observational records the time series might still be relatively short, but in general our North Atlantic region calls for as long time series as possible to establish a “normal” state.

We have analyzed North Atlantic Sea Surface Temperature, temperature of Atlantic Water in the Barents Sea, Surface Air temperature on a number of stations in the North Atlantic, and also time-series of Sea Level Pressure. All these time-series show evidence of strong long-term climate fluctuations with periods longer than 50 years. One especially interesting region is the Barents Sea, where large air-ice-ocean variability is also evident in proxy records of past climate conditions. This suggests that the Barents Sea has had an important role in Northern Hemisphere climate for, at least, the last 2500 years.

Coupled climate model simulations capture such large fluctuations, which result from the interaction between ocean and atmosphere in the North Atlantic. The North Atlantic circulation changes impact Arctic sea ice and surface temperature, and the changes in the Arctic are found also to influence the North Atlantic some years later. The physical mechanisms behind this variability offers a potential to predict these variations that can both mask and enhance global warming, particularly at a regional level such as the Arctic.

## Vegetation mapping of Northern Fennoscandia utilizing satellite remote sensing data

*Bernt Johansen*

Northern Fennoscandia represents a transition area between humid, oceanic parts in the west and drier, more flat, continental areas towards the east. It also includes the transition from boreal forest in the south to treeless Arctic tundra in the north, interrupted by large, treeless mountains. Regarding botanical research within the area, most efforts have been put to record the occurrence and distribution of different plant taxa. Fewer attempts have been made to work out vegetation maps of these northern regions. However, on Swedish side of the border large parts of mountain areas have been covered by conventional vegetation maps, while both in Finland and Norway only minor areas are covered by such maps. Further, the lack of correspondence with respect to mapping methods and differences in primary data sources have made it difficult, so far, to create consistent vegetation maps covering the entire region. The overall aim of this presentation is to present and discuss the most recent vegetation map developed for the Northern Fennoscandia. In order to create the map product, several Landsat TM/ETM+ images have been processed during six operational stages including: (1) spectral classification, (2) spectral similarity analysis, (3) generation of classified image mosaics, (4) ancillary data analysis and integration, (5) contextual correction, and (6) standardization of the final map products. Analysis performed on the spectral-only data is often denoted the pre-classification stage of the process (steps 1-3), whereas the post-classification part involves analysis and integration of ancillary data to the pre-classified product and a subsequent contextual corrections of misclassified classes (steps 4-5). In the final standardization stage the defined classes are put into a general botanical frame valid for the study region. The developed map is differentiated into 21 map units. Five of the units are located to forest areas drawing an overall distinction between coniferous forests and different types of deciduous birch forests. Two of the map units are associated to bogs and mires. Ten of the units are describing the mountain vegetation with a main distinction along the ridge-snowbed gradient. The four remaining classes are defining areas of glaciers, agricultural fields, urban areas and areas of open water. The accuracy of the map is evaluated in areas where access to traditional maps has been available. The map product is in digital format, which gives the opportunity to produce maps in different scales. The produced vegetation map has been a key element in the NCoE/Tundra project funded by the Nordic Council of Ministers through NordForsk. The map has given input to several research aspects of the Tundra program such as new delineation of tundra areas in Scandinavia, the relationship between snow and vegetation, reindeer range studies, climate impact studies, and land use aspects for the reindeer herders.

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# Climate policy implications of expanded international bioenergy trade

*Olle Olsson*

The recent decade has seen a strong expansion of international trade in different bioenergy carriers, most prominently bioethanol, biodiesel and wood pellets. This is a response to policy measures in different countries and regions that incentivising the use of bioenergy as an alternative to fossil fuels in transportation (bioethanol & biodiesel) and generation of heat & power (wood pellets). Bioenergy trade has the potential to support an effective fact that bioenergy markets are international but policy has also highlighted important issues that need to be addressed in the context of climate policy design. This is relevant for not only mitigation but also adaptation and especially the inter-relationships between mitigation and adaptation. For mitigation, an issue has been the one of carbon accounting, where there are risks of bioenergy emissions being unaccounted for. It is also important to ensure that growing demand for biofuels does not have an adverse impact on land-use patterns and adaptive capacity, as this could entail a conflict between mitigation and adaptation policies. These issues are especially important to highlight as they show a previously understudied phenomenon where mitigation policies in one part of the world (e.g. the Nordic region) could have effects for adaptation policies very far away.

## Increasing black carbon deposition warming the Arctic

*Meri Ruppel, Joana Soares, Elisabeth Isaksson and Atte Korhola*

The amplified warming of the Arctic is partly caused by positive feedback processes connected to the retreating snow and ice cover. Black carbon (BC) is a fine particle that strongly warms the atmosphere. Its climate effects are intensified in the Arctic where its deposition decreases the reflectivity of snow and ice and hastens their melt. Long-term information on BC values is essential when assessing the role of BC in past, present and future Arctic climate change. Atmospheric Arctic BC concentrations have been monitored since 1989, and indicate decreasing values. However, ice cores and sediments are the only means to study BC deposition, and especially over longer timescales beyond the present-day observations. Ice core and lake sediment records from the European Arctic indicate increased BC deposition in the area from 1970 to the present. This unexpected result is supported by model results suggesting that BC deposition trends may differ from atmospheric concentration trends. Plausible explanations for the recorded BC deposition increase are flaring emissions from northern Russia, and rising temperatures increasing the washout efficiency of BC with precipitation. The global climate is affected by increased BC deposition in the Arctic, as the fundamental role of the Arctic in cooling the Earth's climate is hampered by the hastened retreat of the snow and ice cover in the Arctic.

This is an abstract to the Side-event A: The Top-level Research Initiative of Nordforsk: Results and interactions with and within the Nordic Centres of Excellence on Effect studies and adaptation to climate change!

## How to preserve the tundra in a warming climate

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The Arctic region will warm more rapidly than the global mean, influencing dramatically the northern ecosystems. At the same time, our societies convert towards urbanized, highly educated, service-based culture, where a reducing proportion of the population will earn its livelihood from primary production. We study various ecosystem interactions in a changing climate and integrate these with reindeer husbandry and the indigenous Sámi culture dependent on it. Potential climate impacts include the transformation of arctic-alpine tundra into a dense scrubland with conceivable consequences to reindeer husbandry, but also global warming due to decreasing albedo. The administrative and ecological processes of the social-ecological system (SES) of reindeer husbandry do not always match in practice: management priorities and administration may conflict with local social and ecological processes, bringing about risks of environmental degradation, loss of biodiversity and defeat of traditional livelihoods. We hypothesize the plausibility to support the indigenous reindeer herding livelihood against rapid external changes by utilizing the migratory reindeer grazing system of the Sámi as a management tool for climate mitigation by sustaining the high-albedo tundra. Our first-of-a-kind satellite-based high resolution vegetation map covering Northern Fennoscandia allows detailed management plans, whereas our ecological research demonstrates the crucial role of herbivory on arctic vegetation communities. Interactive workshops with reindeer herders offered indigenous knowledge of state and changes of the ecosystems, and reflect the threats and expectations of the herders. As a synthesis of our transdisciplinary approach, we have built scenarios of the future development of reindeer husbandry in Fennoscandia.



## Fundamental process studies in the context of changing Arctic climate

*Erik Thomson and Jan Pettersson*

Currently, a consensus exists that observed environmental changes are amplified in the Arctic, however the reasons for the observed amplifications are less clear. Within the Arctic there are natural feedbacks that accelerate changes and the unique and pristine nature of the region may also make it more susceptible to current and future change. Within the context of the Nordic Top-level Research Initiative, Cryosphere-Atmosphere Interactions in a Changing Arctic Climate (CRAICC), many fundamental processes that underlie feedback mechanisms have been investigated. Here we present an overview of experimental and theoretical work related to ice particle formation, clouds, and effects therein of anthropogenic inputs like ship traffic. These fundamental studies are put into the context of climate science and the implicit implications for water cycling, heterogeneous chemistry, etc. The Nordic countries sit at a sensitive crossroads with respect to Arctic climate and global development and are thus susceptible to undue climate pressure. By highlighting results from CRAICC we demonstrate how increased understanding of fundamental atmospheric processes have myriad benefits and in particular promote a unified regional understanding.

## Black Carbon: 30-years trends over the Arctic

*Joana Soares, Meri Ruppel and Mikhail Sofiev*

Black carbon (BC) is an important climate forcer, in particular over the Arctic. The absorption of radiation caused by BC-containing aerosols over a highly reflective surface, such as snow, will result in a warming at high-altitudes (haze layer) and will warm the surface due to an increase of the downward longwave radiation. In snow, BC will increase the melting of the snow pack.

Long-term modelling studies show that BC surface air concentrations in the Arctic are decreasing throughout the last 30 years, due to the decrease of BC emissions in a global scale. This study shows that for the same period, deposition might not show the same decreasing trend as concentrations. This implies that deposition patterns are changing and they can be spatially different. Trends for wet and dry deposition may differ substantially, depending if the sites are continental - closer to BC sources - or remote. In general, positive trends for dry deposition are related to local emissions being increasing and for wet deposition are due to the warming of the atmosphere. The main outcome of these positive trends is the increasing of BC concentration in snow. This has been reported in core measurements in Svalbard, Norway. The understanding of wet and dry deposition trend will allow understanding the impact of BC on ecosystems and possible feedback to the climate.

## Adapting to Coastal Ocean Acidification – a “wicked problem” for coastal governance?

*Marianne Karlsson, Carlo Aall, Lucy Greenhill and Halvor Dannevig*

The Norwegian government has stated an objective to achieve ‘blue’ growth in the coastal zone in accordance with criteria for environmental sustainability. In order to maintain and expand coastal activities (e.g. aquaculture, shellfish, kelp production and tourism) and to ensure resilience of coastal ecosystems, governance needs to adapt to emerging changes including ocean acidification (OA). Major knowledge gaps surround OA and OA impacts, particularly relating to coastal areas, and research on the societal impacts and potential policy responses is scarce. This paper examines coastal governance arrangements in Norway and Scotland and explores how different institutional elements may enable or constrain adaptive governance in relation to complex socio-ecological challenges such as climate change and OA. Given that adapting to OA is a novel issue facing coastal communities, we draw on experiences from the institutional capacity for climate change adaptation more broadly, and ask whether such lessons are applicable for responding to OA. A general conclusion of the paper is that the transferability of the institutional knowledge for local climate change adaptation is low for the specific challenges facing adaptation to coastal OA. The novelty of OA and its impacts for society render it difficult to relate to adaptation actions, whereas climate change adaptation can to some extent rely on historic experiences with handling extreme events whereas there are no experiences with how to deal with the effects of OA. Yet, we argue that there are lessons to be learned from existing governance mechanisms in dealing with complexity and variability which may be applied to emerging challenges such as OA, including for example, multi-actor dialogue and collaboration.

## Earth System Feedbacks in the Northern High Latitudes

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The northern high latitudes are undergoing rapid changes due to global and regional anthropogenic influence. Due to a variety of Earth system feedbacks, the response of the Arctic and high-latitudes to present-day and future perturbations is extremely complex. Among the traditional Arctic climate feedbacks is the sea-ice-albedo feedback, whereby declining high-latitude sea ice cover would allow more heat to be absorbed by the Arctic ocean. Furthermore, recent studies have indicated potentially strong feedback mechanisms acting via aerosol-climate interactions, initiated by changes in aerosol emissions from e.g. the Arctic ocean or high-latitude vegetation. One of the main aims of the Nordic Top-level Research Initiative CRAICC (Cryosphere-Atmosphere Interactions in a Changing Arctic Climate) was to identify knowledge gaps regarding Arctic feedback mechanisms and to quantify several unexplored high-latitude interactions. The theoretical and experimental research in CRAICC allowed to further develop state-of-the-art Earth System Models, which were then driven by various anthropogenic scenarios in order to analyze the high-latitude response and feedbacks. Here we give an overview of the main CRAICC results regarding northern high-latitude Earth System feedbacks, specifically focusing on feedback mechanisms involving aerosol-chemistry-cloud-climate interactions.

## Climate adaptation to coastal flooding - decision support in the Hazard Support project

*Helen Andersson, Christian Dieterich and Magnus Hieronymus*

Global mean sea level is rising. At the regional level this can increase the intensity and frequency of coastal flooding. The combination of factors such as mean sea level rise, land uplift, tides, local winds, air pressure, and topography will give different future flood risks at different locations along the Swedish coast, which calls for different adaptation actions. Further, the climate-change information and impact data needs to be tailored in order to meet different end-users' needs.

We will here approach different stake-holders need of climate impact information in order to produce best scientific practice guidelines and to handle changing climate-projection information in their adaptation plans. A thorough analysis of historic events provides information on return periods in present climate. However, due to the relatively short observation periods the information on longer return periods is limited. We will use numerical models to complement the observations and to increase the statistical information base. It will also enable investigation into nonlinear interactions between mean sea levels and extreme levels. By using different RCP climate scenarios, downscaled with a regional coupled climate model, atmospheric forcing is available to project possible changes in extreme sea levels into the future.

## Sea Level Change for Norway: Past and Present Observations and Projections to 2100

*Matthew J R Simpson, Jan Even Ø Nilsen, Oda R Ravndal, Kristian Breili, Hilde Sande, Halfdan P Kierulf, Holger Steffen, Eystein Jansen, Mark Carson and Olav Vestøl*

Changes to mean sea level and/or sea level extremes (e.g., storm surges) will lead to changes in coastal impacts. These changes represent a changing exposure or risk to our society. Here we try to synthesize our understanding of past and present observed sea level changes for Norway, as well as providing sea level projections up until 2100. Our primary focus is changes to mean sea level but we also give updated return heights for each coastal municipality in Norway.

We first analyse observed sea level changes from the Norwegian tide gauge network and from satellite altimetry. After the tide gauge data have been corrected for the effects of glacial isostatic adjustment, we show that 20th century sea level rise in Norwegian waters is broadly similar to the global average rise. Contributions to the observed sea level change and variability are discussed. We find that rate of sea level rise along the Norwegian coast is significantly higher for the period 1993–2014 than for the period 1960–2010. It is unclear, however, to what extent this higher rate represents natural variability rather than a sustained increase owing to global warming.

Our regional sea level projections are based on findings from the Fifth Assessment Report (AR5) of the Intergovernmental Panel for Climate Change (IPCC), and the Coupled Model Intercomparison Project phase 5 (CMIP5) output. Projected ensemble mean 21st century relative sea level changes in Norway are, depending on location, from -0.10 to 0.30 m for RCP2.6, 0.00 to 0.35 m for RCP 4.5, and 0.15 to 0.55 m for RCP8.5. The projected pattern of relative sea level change is governed by the vertical uplift rates and can differ as much as 0.50 m from place to place. The projections presented here are given with corresponding 5 to 95% model ranges which are defined as the likely range in AR5 ( $P > 66\%$ ). Quantifying the probability of levels above the likely range (i.e., the upper tail of the probability distribution) remains difficult because information is lacking. And of particular concern is that the ice sheet contribution might have a skewed distribution, which would mean values in its upper tail would be quite large.

Finally, we show how the estimated return heights can be combined with our regional sea level projections to provide allowances. Allowances give the height by which an asset needs to be raised so that the probability of flooding remains preserved for a given sea level change. A possible attractive option in planning.

## What role do professional associations and trade unions play in climate change adaptation?

*Maja Karoline Rynning, Rasmus Benestad, Ane Hagetvedt, Anders Bjerga and Lars Slåke*

Professional groups and trade unions are expected to play a role in questions concerning the Norwegian society, both when it comes to professional matters as well as politics. The depth of such a change is portrayed in the JPI Climate, describing how the adaptation to climate change and the transition to more sustainable solutions is envisaged for Europe. It relies on changes in professional codes of conduct and a shared understanding of purpose, and can only be carried out efficiently if professional societies and trade unions are included. Furthermore, the idea of a sustainable green shift can only take place with efficient cross-disciplinary communication and cooperation. Tekna is a professional society with 70000 members holding a master's degree in technical education, engineering or natural sciences, and represents an extensive professional network which embraces many different disciplines. Tekna has ambitions to contribute with technical solutions required for a sustainable 'green shift'. The association is ideal for connecting experts from different disciplines, and it has established a dedicated subgroup called 'Tekna Klima' which is working to reach these goals. Tekna Klima has participated in hearings in the parliament, held training courses, organised seminars including sessions for teachers and schools, and supported work to enhance awareness about climate change. Some of the objectives include keeping a dialogue between the climate science community and the petroleum sector and also to create a climate FAQ which will help the users to navigate through the jungle of information that exists. The ultimate goal of the FAQ is to provide reliable and objective information and knowledge to the user. Another aspect of Tekna is its trade union role, representing the workers rights. These too must be accounted for in the grand vision of a green society, mitigation and climate change adaptation.

## To optimize climate adaptation in land use planning when responsibility for measures are decentralized

*Charlotte E Cederbom and - The Climate Adaptation Working Group*

Local municipalities and individual land or property owners have the main responsibility for concrete climate adaptation measures in Sweden. They have to adapt existing buildings and infrastructure to increasing sea-level, more intensive rainfalls and increasing water flows. Moreover, they must consider huge uncertainties in climate change predictions for the coming centuries during their land use planning. To enable cost-effective and successful climate adaptation for society at a national scale, it is necessary for national and regional authorities to provide appropriate climate services in form of continuously updated basic data and new methodologies as well as knowledge transfer and expert support to the local actors.

Here we present an example of how research, implementation and knowledge transfer can be integrated to optimize climate adaptation in land use planning and landslide risk management at a national, regional and local level. The Swedish Geotechnical Institute (SGI) is a national authority that is commissioned by the government to conduct landslide risk assessments along prioritized, main rivers in the country to meet a changing climate. Experiences from end-users of our risk assessments lead to development of new methods that we implement during the investigation. Knowledge about the methods are being spread through workshops and courses to enable implementation in other regions and disciplines. To spread data from our risk assessments, that are both detailed enough to enable planning at a local level and visualized well enough to be understandable for local policy makers, different web applications are being developed. Moreover, seminars are being held to increase the awareness among the different local actors about their specific role. Finally, we loop back to research and national and regional policy making by emphasizing additional needs of research and decision support that we identify during our contact with the local actors.



## Future climate projections for the Baltic marine ecosystem

*Helen Andersson*

Climate-model results for the Nordic area, based on IPCC scenarios, indicate that a significant warming of the region can be reality before the end of the 21st century. The global warming will have large impact on the marine environment of the Baltic Sea with, for example, increased water temperatures, reduced sea-ice cover, decreased oxygen concentrations, increased rates of biogeochemical processes and larger nutrient loads flushed out from land. All together this means that the severe eutrophication with intense algal blooms and hypoxic conditions of today's Baltic proper may become even worse in the future. Interactions and feedbacks from climate change can be rather complex, especially in combination with other human activities, such as eutrophication, fishing or pollution. The understanding of the possible effects on the Baltic Sea marine environment from different anthropogenic factors will provide decision support for effective ecosystem management and protection of marine resources. We will here show how projections from the climate models, together with socio-economic scenarios, have been used to force a spatially resolved, coupled physical-biogeochemical model of SMHI to simulate the future evolution of the Baltic Sea ecosystem in terms of trends in nutrients, oxygen, primary production and other relevant processes. The projections are developed in the frameworks of the Nordforsk funded Nordic Center of Excellence NorMER, the BONUS projects BIO-C3 and BalticAPP, and the H2020 project CERES.

## Climate change adaptation action plan for sustainable land use

*Kerstin Konitzer, Lisa Van Well and Charlotte Cederbom*

The Swedish Geotechnical Institute (SGI) is currently developing a national action plan for the land use sector focusing on sustainable ground construction, land use planning and soil environmental issues in a changing climate. The action plan will define targets and measures valid for both public and private actors. SGI is one of several national authorities that are developing an action plan for climate adaptation within its sector during 2016. These voluntary development action plans are partly financed by the Swedish Government and the Climate adaptation allowance. The work is carried out in the absence of a mutual framework, such as a national strategy for climate change adaptation, but within the context of a number of national and regional investigations together with local measures taking place.

The aim of this presentation is to present experiences and identified challenges from the pioneering work with the action plan. We will present the strategy we have chosen for involving actors for sustainable community development in the sector, and that is important for identifying crucial development needs and for subsequent implementation. Particular emphasis will be on our work to develop indicators for evaluating how successful the adaptation measures in the sector are. Additionally, we elaborate on how we engage the various experts at SGI for subsequent knowledge transfer and governance towards identified goals.

## Implementation of state-of-the-art ternary new particle formation scheme to the regional chemical transport model PMCAMx-UF in Europe

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The particle formation scheme within PMCAMx-UF, a three dimensional chemical transport model, was updated with particle formation rates for the ternary H<sub>2</sub>SO<sub>4</sub>-NH<sub>3</sub>-H<sub>2</sub>O pathway simulated by the Atmospheric Cluster Dynamics Code (ACDC) using quantum chemical input data. The model was applied over Europe for May 2008, during which the EUCAARI-LONGREX campaign was carried out providing observed vertical profiles of aerosol number concentrations. The updated model reproduces the observed number concentrations of particles larger than 4 nm within one order of magnitude throughout the atmospheric column. This reasonable agreement is even more encouraging considering the fact that no semi-empirical fitting was needed to obtain realistic particle formation rates. The cloud adjustment scheme for modifying the photolysis rate profiles within PMCAMx-UF was also updated with the TUV (Tropospheric Ultraviolet and Visible) radiative transfer model. Results show that although the effect of the new cloud adjustment scheme on total number concentrations is small, enhanced new particle formation is predicted near cloudy regions. This is due to the enhanced radiation above and in the vicinity of the clouds, which in turn leads to higher production of sulfuric acid. Furthermore, the sensitivity of the results to including emissions from natural and anthropogenic sources shows the potential to improve the agreement between the predicted and observed particle number concentrations.

## Transboundary impacts of climate change on the energy sector: A conceptual framework

*Fanny Groundstroem and Sirkku Juhola*

Potential implications of climate change have hitherto been assessed primarily within national contexts, focusing on the impacts associated with a changing national climate. It is becoming increasingly clear, however, that climatic and environmental change also need to be viewed in a broader international perspective, as countries may experience repercussions from climate change impacts occurring in faraway regions through e.g. disruptions to international trade, implications for the global economy or the movement of people. We refer to these repercussions as transboundary impacts of climate change. Here, we propose a conceptual framework for facilitating the identification of and research on these transboundary impacts.

A sector for which transboundary impacts may be especially important is the energy sector, due to the highly interconnected globalized market for energy. Furthermore, the intended shift in energy systems in the foreseeable future towards renewables and low-carbon energy will have profound implications for the energy sector and bring about new challenges and opportunities. Therefore, we will apply the framework to the energy sector of the Nordic countries, because of their highly ambitious targets for achieving a renewable-based low-carbon energy system by the year 2050. Moreover, the Nordic countries have quite different opportunities and possibilities for producing renewable energy; Finland and Sweden have vast bioenergy resources, Norway have plenty of hydropower potential, Denmark has substantial plans for development of wind energy, and Iceland's energy system is already based to a large extent on geothermal energy. With the help of the framework we aim to answer the following research questions:

How could transboundary impacts of climate change affect a future low-carbon energy system?  
Which transboundary impacts are likely to be of most importance for the production, supply and use of different energy sources within the Nordic countries?

We will use the framework to identify potential future interconnections between the Nordic energy sector and the rest of the world, and potential transboundary impacts of climate change that may arise through these interconnections. For instance, the European Union is aiming for a more integrated electricity transmission grid in the future, which may entail new roles for the Nordic countries as providers of cheap and clean electricity to the European mainland. The import of bioenergy into the Nordic countries is projected to increase substantially in the future, with the importance of South America as a trade partner potentially increasing. The Nordic countries may also be affected indirectly through e.g. major changes to the global energy market, which may cause fluctuations in prices. For different energy sources, the Nordic countries may thus be either a receiving, sending or a spillover system, for which different transboundary impacts will be more or less important.

The framework is based on the concepts of societal teleconnections (Moser & Hart 2015) and telecouplings (Liu et al. 2013), and provides a comprehensive foundation for future research on transboundary impacts of climate change. It also helps practitioners within policy and adaptation planning to identify and assess which transboundary impacts may be of importance to them.

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## Coastal community resilience in climate adaptation and risk reduction

*Mie Thomsen and Carlo Sorensen*

Storm surge impacts on the Limfjord coasts of Denmark are exacerbated by the expansion of the Thyborøn Channel that causes increased water transport into the fjord from the North Sea. This, in combination with sea level rise, jeopardizes the strength of existing flood protection and challenges the local municipalities to implement additional measures. For the fjord towns of Thyborøn (pop. 2100, located towards the North Sea by the Thyborøn Channel) and Løgstør (pop. 4000, located approximately 80 km east from the North Sea) flood hazard, vulnerability, and risk assessments and mapping are combined with community resilience studies to provide the corresponding municipalities with a more elaborate knowledge platform for climate adaptation and disaster risk reduction. Community resilience is investigated in four dimensions (information & communication, community competence, social capital, and institutional capacity) from +25 semi-structured interviews conducted with local citizens, municipal level employees as well as national government officials. Despite facing the same flood hazards, the two communities have different histories, social structures, and previous flood experiences and, accordingly, have different resilience strengths and limitations inherent. Thyborøn emerged over the past century as a fisheries town protected from the North Sea by large sea dikes constructed by the national government. Life in a harsh physical environment and no significant flood accounts in decades, means that neither the community nor the municipality perceives floods as any immediate threat. Municipal adaptation planning is slowly forming but hitherto without engaging the local community, and the town has no formal emergency preparedness plan. In contrast, the medieval town of Løgstør last experienced severe floods in 1981 and 2005 which led to the construction of a sea wall, community involvement, and detailed emergency management setup. The Thyborøn community has a reputation of 'acting on their own' and the citizens do not -neither individually nor collectively, ask e.g., the municipality for assistance. They do possess the ability to muster volunteers in large numbers when needed, however. Here, the current lack of information from the municipality is noticeable and community involvement, to go along with current scientific investigations for climate adaptation, will increase community resilience and allow for better and more integrated solutions. The Løgstør community resilience is strong as the locals are knowledgeable about the flood risk, have good work relations with the municipality, and have detailed disaster preparedness plans. The plans are not flexible which may limit the community resilience, however. In addition, amenity - or the attractiveness of the town to tourists and residents, is a strong factor to both the locals and the municipality and is weighed at almost equal level to safety and risk reduction in adaptation planning. More specifically this means that the heights of existing sea walls are a compromise between safety against floods and sea view. Thus, although the community is well prepared for the next extreme event and has the ability to recover, the level of protection indicates that floods may occur at unnecessary high frequencies thereby degrading the community resilience to an undesired extent. In conclusion, the study points to the potential in combining and merging natural and social science approaches for climate adaptation and disaster risk management to strengthen municipal decision-making, allow for better planning measures, and to strengthen community resilience.

## 1 x 1 km climate and hydrological projections for Norway

*Wai Kwok Wong, Astri Tale Eirum, Hege Hisdal and Nils Kristian Orthe*

Outputs of global or regional climate models (GCM/RCMs) are often flawed with systematic biases despite recent progress in climate modelling, particularly in simulations of present day climate. The modelling results can be very different from what have been observed which hamper their direct use in climate change impact studies. Moreover, impact models often require data of higher spatial resolution than climate models usually can provide. A post-processing of GCM/RCM outputs is therefore necessary to obtain plausible time series in an appropriate scale for use in local impact studies. It is, however, important to bear in mind the drawbacks of post-processing when interpreting the study results.

In this study, an empirical quantile mapping method (EQM) was used to bias-adjust and downscale precipitation and temperature for Norway for an ensemble of 10 EURO-CORDEX GCM/RCM simulations, each representing two alternative emission pathways (RCP4.5 and RCP8.5). The original GCM/RCM outputs with a resolution of 12.5 x 12.5 km were first re-gridded to 1 x 1 km. A transfer function based on empirical cumulative distribution functions (CDFs) for both observed and modelled variables was applied to adjust values from the climate projection quantile by quantile so that they yield a better match with the observed. Calendar-month and grid-cell-specific transfer functions were derived and EQM was used to the daily simulated data. These datasets covering the period of 1971-2100 were then forced with a spatially distributed, gridded version of the HBV precipitation-runoff model to generate daily time series of different hydrological components such as runoff, evapotranspiration, snow water equivalent and groundwater. These high-resolution gridded datasets despite their limitations form an important basis for different impact studies on a national and local scale. In addition, an interactive web for data dissemination was developed. Key functionality of the application is temporal and spatial selection of the available datasets. The system will also support various map projections and formats for downloading.

## Modelling storm runoff and flooding in urban catchments including runoff from green areas: Nørrebro, Denmark

*Alexandra Georgiana Ioan, Roland Löwe, Sara Maria Lerer, Sønderup Henrik, Anton Anton, Arnbjerg-Nielsen Karsten and Mikkelsen Peter Steen*

In the recent years natural phenomena such as flood have cost billions of euros and numerous losses of human life. Over the next decades, extreme weather events are expected to become even more frequent due to climate changes (Arnbjerg-Nielsen, Leonardsen, & Madsen, 2015). The extent and nature of expected changes varies across the globe. In the past 30 years, changes in rain patterns have been observed in Denmark in terms of extreme precipitation. These changes are mainly visible in the frequency of extreme events, but there is also a tendency for an effect on their magnitude (Arnbjerg-Nielsen, 2012). There are different approaches to adapt cities to these extreme events. One approach is the conventional adaptation where the sewer system is enlarged, but this is not always possible due to very big implementation costs. Another approach is adapting the urban landscape for stormwater management, which is often called Low Impact Development (LID) or Sustainable Urban Drainage Systems (SUDS) and involves elements of Green Infrastructure (GI) (Fletcher et al., 2014). There are several possibilities to 'reconstruct' the cities taking into account the space needed for stormwater. This will allow the cities to redirect the stormwater to areas that are designed and suitable for flooding, inside or outside the cities, during extreme rain events. This approach has become increasingly popular in Denmark over the past few years (The City of Copenhagen, 2015).

In this context, accurate modelling of storm runoff from urban catchments is very important, but it is difficult to achieve because of the complexity of modelling green areas (DHI, 2015). Depending on the local practice, the available software, the data availability, the possibility of data processing, computation time, and even the experience of the modeller, storm runoff from urban catchments can be analysed using different modelling approaches. Choosing the modelling approach, the rainfall loads to the model and the model parameters are very important steps that have to be made with caution, and there is thus a need to establish more precise guidelines to help modellers in choosing the most suitable modelling approach.

The research presented here focuses on the complexity of modelling stormwater movements in urban catchments during extreme events with an emphasis on the consideration of green areas and LID's. Four different flood modelling approaches are developed, tested and compared using the MIKE 2016 software package (DHI, 2016). Storm runoff from urban catchments is modelled by considering green areas through an initial loss in the model or by using Horton's equation where infiltration is an exponentially decaying process with large infiltration capacity in the beginning of the event. The storm runoff from green areas is either included in the runoff model as a runoff that loads the drainage system or by loading on to the 2D surface model with without previous interaction with the sewer network. In Denmark the adopted modelling approach is to consider both paved and green urban areas through an initial loss in the runoff model a fact that may generate unrealistically loading of the sewer system if the runoff from this type of areas becomes a significant part of the total runoff model. Also there is a lack of experience in modelling the effect of the LID's in extreme rain event.

The presented modelling approaches are applied to the 276 ha area of Nørrebro, Denmark where a large number of Lid's measures will be implemented as part of the Copenhagen cloudburst management plan (The City of Copenhagen, 2015). No direct model validation will be possible within this research because observations of flooding are not available. However, we can employ model-to-model comparison to investigate the influence of different choices that need to be made in the modelling process in order to achieve a suitable representation of the green infrastructure in modelling floods.

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## The legacy of extreme sea levels for the assessment of future coastal flood risk – A review of methods applied in Denmark, Germany and Norway

*Jan Even Nilsen, Carlo Sørensen, Sönke Dangendorf, Matthew J.R. Simpson, Oda Ravndal, Hilde Sande, Per Knudsen, Arne Arns, Jürgen Jensen and Per Sørensen*

The coasts of Denmark, Germany and Norway face similar hazards from storm surges governed by eastward propagating atmospheric lows. Surge and tide levels, as well as their corresponding impacts, vary between storms and location. The exposure and physical vulnerability of the coastline is also not evenly distributed. National methodologies for assessing extreme events generally differ in some way. For example, the statistical methods applied in extreme value analysis, projections of future changes in extremes, and/or approaches for dealing with coastal flood risks. This includes local to regional climate change projections for future sea extremes, and, for instance, variations due to location, morphodynamic change, and glacio-isostatic adjustment. Next, the transformation of this knowledge to concrete impact and design measures and its use in national and local governance adaptation schemes in the three countries is discussed. Here, national approaches to deal with risk, risk acceptance and uncertainty vary, among other factors, as a result of the different assessments of extreme events. In hazard and vulnerability assessments, for instance, where results are highly dependent on the quality of the underlying observational data and statistical methods in use, it is necessary to gain a deeper understanding of the physical processes (i.e. the atmospheric and oceanographic genesis of storms) in order to make robust strategies for adaptation and risk reduction. Inasmuch as the countries bordering the northeast Atlantic Ocean and the North Sea deal with similar coastal hazards and climate change challenges, the development of enhanced scientific transnational collaboration to share knowledge and views regarding future impact from storm surges is suggested. This will provide more robust measures of mitigation and adaptation and it will secure a wider dissemination of results across levels of governance and between the northern European countries.

## From Concepts To Actions For A Proactive Adaptation Of Cities: Incorporating The Knowledge And Practices Of Designers In A Design-Aid Tool

*Maja Karoline Rynning, Catherine Dubois, Marion Bonhomme, Luc Adolphe, Geneviève Cloutier, Serge Faraut, Bernard Ferries, Corinne Sadokh, Anne Péré and Sandra Marquez*

Cities are particularly vulnerable to the consequences of climate change, thus adaptation is of high urgency. Urban development projects represent opportunities to strengthen a city's level of adaptation. Integrating this issue at the early stages of a project is key to a robust result, and Architects and Urban Designers can play a key role in this matter. However, barriers persist as adaptation remains too little integrated in current design practices, and there is a lack of appropriate methods. Tools have been developed, but are seldom employed by practitioners. They are often too specific for the multi-scale design project, or require particular skills. A disparity exists between the suggested support, and the needs of the professionals.

CapaCity is a research project between Toulouse (FR) and Quebec (CAN) that aims at developing a prototype design-aid tool to strengthen the adaptive character of urban development projects, destined to practitioners. Part of its novelty is the attention given to design practices and methods through a series of consultations with professionals, and through an interdisciplinary research team including urban practitioners and researchers with a design background. The suggested presentation concerns the project as a whole, with particular attention to results from the consultations: a questionnaire with over 100 respondents, and two design workshops. The goal was to assess design methodology, the use of data and knowledge, the employment of tools, and the designers' knowledge of, and ways of dealing with, consequences of climate change.

The questionnaire showed that simulation programs and GIS-software were very little used, underlining the observed gap between frequent tools and actual design practices. It also showed that designers tend to see climate adaptation as strongly related to other issues of an urban project, for instance public health or the quality of urban spaces, and thus to be solved in parallel with these.

The workshops demonstrated that through testing potential solutions designers identify interdependencies among elements in a project. Solutions were evaluated in an iterative manner, looking at their impact on different aspects. To prevent unwanted consequences, but also to exploit a win-win potential. Indeed, the use of one solution to solve several issues was often observed. Interestingly, solutions often had an adaptive potential, although rarely identified as such. This confirms to some extent the questionnaires regarding how designers see climate issues in an urban design context. It also shows latent capacities among existing design practices that can be built upon in terms of climate adaptation. Finally, the main source of knowledge was the professional experience, an essential insight with regards to knowledge-transfer between research and practice.

In addition to identifying important characteristics for the prototype tool, the consultations underlined the need to strengthen the dialogue between research and practice. Combined this could increase the effect of solutions and measures, reinforcing a city's adaption to climate change. Through a better integration of adaptation in urban practices, the CapaCity-tool might also contribute to facilitating such interdisciplinary cooperation between research and practice.

## Climate services - targeting the user

*Åsa Sjöström*

How can we make sure that the climate services we produce really become services for society? That they are used in the making of those every-day decisions that affect us all - the planning of roads, the building of new homes, the protection of ecosystems, the use of drinking water resources.

Increasingly, the need to adapt the activities of society to a changing climate is becoming understood and accepted, in parts of society where it has not been apparent before. This produces new challenges to the providers of climate services. We need to understand the needs of these new users, and learn how to make our work relevant to them. We need to answer the questions of society, and provide the information it needs to build a sustainable future.

## Skilful prediction of Barents Sea ice cover

*Tor Eldevik, Ingrid Onarheim, Marius Årthun, Randi Ingvaldsen and Lars Henrik Smedsrud*

The Barents Sea is host to Norway's main fisheries, northern sea routes, and for Arctic-ward expansion of oil and gas exploration. All relates critically to the wintertime marginal ice zone and sea ice extent. Here we present a relatively simple framework for predicting the sea ice cover one to two years into the future. The basis is the observed strength of the Gulf Streams northernmost limb as observed by the Institute of Marine Research at the Barents Sea's western entrance and the present winter's sea ice cover. The framework is skilful when considered retrospectively (1979-2014), and has correctly predicted an increase and then a decrease for the winters 2015 and 2016, respectively. We will here in particular present our forecast for the coming winter of 2017.

## Mapping uncertainties - making sense and use of probabilistic flood maps

*Christoffer Carstens, Sara Andersson and Ola Nordblom*

In many EU states, the EU floods directive has highlighted the need for detailed information on flood events and been a driver for many comprehensive flood inundation studies. In Sweden 18 areas were selected for further studies and development of flood risk management plans, during the first cycle of the directive. A central part of the work was the flood hazard maps and the flood risk maps.

Uncertainties in flood inundation maps are abundant in studies of the present climate and even more so under the perspective of continuous climate change. The uncertainties also differ in terms of character, ranging from parameter uncertainties to lack of data to differences between different models and totally incomparable scenarios (e.g. RCPs). Even so, most flood maps are still being made in a deterministic way and uncertainties are not incorporated in any quantifiable way in the reports. In the Swedish case, this was also true. This study investigates the uncertainties of a number of different sources, viz. roughness coefficients and the return period flood rates for one of the selected Swedish sites. Furthermore a method for integrating and distinguishing the uncertainties of the climate models and scenarios was developed. Data from nine climate models and two RCP scenarios was used. The method combines scenario analysis, GLUE calibration and Monte Carlo analysis to produce probabilistic flood inundation maps and clear diagrams to present the variations between scenarios and models.

Even if the general advice from expertise is to include and present the uncertainties in flood forecasting, this is still rarely the case. Uncertainty analysis is still somewhat thought of as a complicating issue and difficult to understand and present at stakeholder level. This is somewhat paradoxically, since our study suggests that stakeholders at the local level are fully aware of these uncertainties and much of the critique of the flood hazard maps was concentrated around the difficulties of the produced maps to agree with actual flood events. Hopefully the presented methodology could help avoid some of these situations as well as providing help in how to deal with and present differences between climate models and scenarios.

## Climate change, endogenous adaptive capacity, and frontier areas, the case of Tiksi, Sakha Republic, Russia

*Da Cunha Charlotte, Nikulkina Inga, Vanderlinden Jean-Paul, Salakhova Dina, Shadrin Vyacheslav, Sukneva Svetlana A, Maximov Trofim H. and Batzan Juan*

ARTISTICC project's goal is to apply innovative transdisciplinary approaches to develop robust, socially, culturally and scientifically, community centred adaptation strategies as well as a series of associated policy briefs. The project is centered on case studies. In Tiksi, a small town in the north of the Republic Sakha (Yakutia - Russian Federation), we analyze how society adapt to current changes and how memories of past adaptations frames current and future processes.

The data have been collected by a literature review, interviews and focus group with local stakeholders and an quantitative survey. Fourteen semi-structured interview and one focus group has been conducted, between 18 and 20 November 2014, seeking to make inferences from a group of respondents selected to represent specific social actors (federal authorities, state authorities, municipal authorities, indigenous people, business and scientists). The qualitative survey was conducted in the Bulunsky region in 2014 (122 respondents). Both surveys aim to describe adaptation initiatives to global changes, with a focus on climate change.

Tiksi is the administrative centre of the Bulunsky region. Its socio-economic development is associated with economic insularity of its territory: a high risk of economic activity and uncomfortable living conditions, caused by the extreme combination of natural factors and lack of development of all types of infrastructure. Nowadays, the changing climate strengthens existing threats and risks and generates new ones. The Bulunsky region should deal with a extremely low and decreasing population rate. It is not only a demographic and economic problem, but it also has ecological and cultural aspects. It is connected to the extinction of the original culture of the northern peoples, including their traditional crafts.

A first analysis of both qualitative and quantitative survey grants access to preliminary results through the definition of four statements about endogenous adaptive capacity of the Bulunsky region:

- 1) Climate is felt by local people. They see vegetation changes, a diminution of snow cover, changes in season, impacts on fishing and reindeers breeding, flooding and coastal erosion, impacts of changing wind and melting permafrost on housing infrastructure, etc.;
- 2) People have others concerns. The quantitative survey highlights everyday problems as high prices, alcoholism and drinking, low salaries and pensions. The qualitative one shows that Tiksi's economy and population rate is extremely linked to military base that depend to federal level.
- 3) For all these concerns, including climate change, funding of solutions come from outside (Sakha Republic, Russian Federation, National and International Research). The economic insularity of the territory and the diminution of military base activities weaken the economic structure. The local authorities propose actions and development plans but they need funding from higher governance level.
- 4) The ongoing changes are transforming reality. Indigenous peoples are more and more often finding themselves in situations where their practice, experience and knowledge cannot help them, even so some local interesting adaptation process have been highlighted by the qualitative survey.

In order to share these results with local communities, we aim to translate these "real life experiments" into an artwork that are meaningful to those affected by climate change. We are initiating an exchange between scientists and a local stage director to create an art and science production that will take the form of a dance show.

## What do climate service users need - and what can they get?

*Erik W. Kolstad*

In the HORDAKLIM project, the aim is to provide climate change scenarios to users: typically planners in municipality administrations. The focus is on Hordaland County in Western Norway, where the geography is characterized by steep mountains and fjords. This means that the local variance of climate change impacts is sometimes huge. The current generation of global climate models are run a resolution of typically 100 km, and the information that these models yield is often completely irrelevant for our users; they need resolutions of <10 km. One of the challenges in the project so far (started in 2015) has been to reconcile the needs of the users with what is actually available. The first stage has consisted of learning about the needs (through visits and workshops), and in parallel, tweaking regional models to best meet those needs. In the next stage, we will run the models and convey the results back to the users. The novelty of the project is the frequent communication between researchers and users, which has been fostered through web interactions and workshops and has provided useful new insights to members of both groups.

## Adapting to avalanche risks and road closure: A case from Northern Norway

*Grete Hovelsrud, Marianne Karlsson and Julia Olsen*

The steep topography in Troms County Northern Norway combined with weather and settlement patterns create conditions for avalanche risks. The risk and occurrence of avalanches lead to road closures that disrupt the transportation of people goods and services and may isolate communities. Climate change is altering the timing frequency and spatial range of avalanche risks. The importance of reliable and predictable infrastructure for rural communities has increased as both businesses and social life are highly interconnected with urban areas and other settlements in the region. At the same time growing demands for personal safety from government authorities result in longer periods of road closures. While avalanche risks and infrastructure disruption are most often assessed in technical and economic terms this paper focuses on the localised experiences of living with and responding to such risks This paper presents findings on how local residents businesses and public service providers in two avalanche exposed settlements experience perceive and adapt to risks related to avalanches infrastructure disruption and isolation. Based on qualitative interviews with local residents and government officials the paper shows that perceptions of risks and what constitutes 'acceptable' levels of disruption vary between and within the two settlements. Further the findings illustrate that residents have developed a range of response strategies to the disruptions caused by avalanche risks. Everyday responses include keeping an extra set of clothing toiletries and medicine on the other side of the avalanche points reducing social commitments during peak season and relying on local knowledge and social networks. More far-reaching responses seek to influence politicians and authorities to implement measures that reduce avalanche risks. The paper argues that the current adaptation strategies might be challenged under climate change and increasing societal demands related to safety and connectivity.



## Co-designing climate service platforms with users : promises and pitfalls

*Rob Swart, Annemarie Groot, Hans-Olav Hygen, Rasmus Benestad, Elinor Forst, Sandrine Dhenain, Karianne de Bruin, Peter Thijsse and Ghislain Dubois*

After “climate services” were put on climate policy and research agendas by WMO in 2009, steps were taken in different countries and networks to operationalize the concept. Here, we focus on Europe, where a Roadmap for Climate Services provides the framework for research in support of the development of an operational climate services in the context of the Copernicus programme, which is aimed to be driven by user demands. Because digital information is not only increasingly accessible to a large and diverse number of potential users of climate services, but is also relatively cheap, the development of climate information platforms is emerging as a core component of various public climate services mechanisms at national and international levels. Such platforms aim to be useful for a wide range of potential users. But do they live up to the expectations? What are the characteristics of effective climate services platforms and which role can they play in a broader range of climate products and services? This paper discusses these questions in the context of a European project (Climate Information Platform for Copernicus - CLIPC) that aims to become the “one-stop-shop” for climate information in Europe. We find that questions to be addressed by a climate information portal are not only very broad because of the diversity of users, but are also changing over time, requiring the design of climate information platforms to be flexible and conscious of the broad context of the information demand. This particularly applies to the design and content of information platforms for non-scientific users.

## A Climate Information Platform for Copernicus (CLIPC): managing the data flood

*Rob Swart, Rasmus Benestad, Hans Olav Hygen, Peter Thijsse, Martin Juckes, Lars Barring, Luis Costa Carvalho, Johannes Lückenkotter, Wim Som de Cerf and Sarah Callaghan*

The FP7 project “Climate Information Platform for Copernicus” (CLIPC) has developed a demonstration portal (the European “one stop-show” for climate information) for the Copernicus Climate Change Service (C3S). The project confronted many problems associated with the huge diversity of underlying data, complex multi-layered uncertainties and extremely complex and evolving user requirements. The infrastructure is founded on a comprehensive approach to managing data and documentation, using global domain independent standards where possible. An extensive thesaurus of terms provides both a robust and flexible foundation for data discovery services and accessible definitions to support users. It is, of course, essential to provide information to users through an interface which reflects their expectations rather than the intricacies of abstract data models. CLIPC has reviewed user engagement activities from other collaborative European projects, conducted user polls, interviews and meetings and has now entered the final phase in which the demo portal is finalized taking into account new features and options in the portal design as suggested by users.

The CLIPC portal provides access to raw climate science data and climate impact indicators derived from that data. The portal needs the flexibility to support access to extremely large datasets as well as providing means to manipulate data and explore complex products interactively.

## Aquaculture and Climate change: Mitigation, adaptation and innovation in industry and management.

*Grete Hovelsrud, Julia Olsen and Arild Gjertsen*

The aquaculture industry is exposed to high variability in weather and is used to cope with such variations. The industry is expected to increase five-fold by 2050, in parallel with climate change which is expected to have both positive and negative consequences for aquaculture. Increased ocean temperatures and an increased frequency in extreme weather are believed to have the greatest impact. This has resulted in new standards for design and construction of aquaculture facilities. Warmer ocean temperatures may also affect farming of species such as salmon and cod. Currently we know that lice is temperature sensitive and that with increased temperature this problem may also increase. Significantly higher summer temperatures in the fjords could increase the likelihood of disease outbreaks and propagation of micro-organisms. Increased precipitation and increased freshwater intrusion into the fjords could also affect current conditions, resulting in changes to how lice and other disease-causing microorganisms are spread. Northward migration of species with higher temperature tolerance may also pose challenges for the operation of aquaculture facilities (jellyfish, algae). The effects of ocean acidification on aquaculture are less known but are expected to be serious for the industry in the long term. Aquaculture is an innovative industry with indirect ramifications for both adaptation and mitigation and industry representatives have pointed out that climate change will enable a significant increase in production. A relevant question is whether the described impacts of climate change is on the agenda in the aquaculture sector. We will discuss the implicit links between climate change, aquaculture business strategies and management policy. The implicit links are found within innovation, mitigation and adaptation in the industry and with respect to policy within traditional environmental concerns. We explore whether the capacity to adapt, mitigate and innovate are affected if these linkages are not made explicit. Increased focus on climate change may likely strengthen the capacity to exploit the projected increased production in aquaculture, but this is set within two Norwegian policy targets; increased production and transition to a green economy. We explore the implications for the sector's ability to meet the cumulative effects of future changes.

## JPI Climate – a European initiative on climate research

*Torill Engen Skaugen Engen Skaugen*

The Joint Programme Initiative on Climate (JPI Climate) is collaboration between 17 European countries. JPI Climate connects scientific disciplines, enables cross-border research and increases the science-practice interaction. JPI Climate contributes to the overall EU objective of developing a European Research Area and is coordinated with the EU Programme Horizon 2020 in support of excellent science, industrial leadership and the European response to one of the great societal challenges of our times, which is climate change.

JPI Climate aims to connect the various research communities with research funders and performing organisations, within and across European countries and beyond Europe. JPI Climate also provides a platform for smarter alignment of national research priorities and a support for high impact initiatives at the European level.

The talk will give information about JPI Climate, how we gain from this JPI at national levels, and how it is possible for researchers, stakeholders and other sectors of the society to contribute.

## Considering Climate Change in Large Infrastructure Projects – Example from Lake Mälaren and Swedish hydropower

*Gunn Persson and Johan Andréasson*

Hydrological changes due to climate change have been a large concern for the Nordic hydropower industry since the late 1990's. On one hand it could give beneficial changes regarding the potential for generating more hydropower, but on the other hand it raises questions regarding the safety of the infrastructure, i.e. large dams, under future climate conditions. Much effort has been spent on how to consider climate change in hydrological design studies and since 2007 it is prescribed, in the Swedish guidelines for hydrological design, that climate change shall be considered in all design studies. How this should be done is however not prescribed and both the available methods and data to do so evolve over time.

The presentation will take up and discuss some of the experiences from communicating climate impact results as decision support to large infrastructure projects, e.g. upgrading of large dams and the reconstruction of the outlet of Lake Mälaren in Stockholm.

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## Regional climate projections of precipitation – why are they so uncertain?

*Asgeir Sorteberg*

As a main driver of changes in water resources, agricultural production and geo-hazards like floods and landslides, knowledge of future changes in precipitation is a key issue in climate change adaption. Future projections of regional precipitation changes often have a much larger spread than temperature projections. In this talk I will summarize some of the key uncertainties; prospects for reducing them and why the uncertainties should be an integral part of any climate change impact study.

## Climate change impacts on groundwater – where are the main uncertainties and can they be reduced?

*Jens Christian Refsgaard*

This presentation assesses how various sources of uncertainty propagate through the uncertainty cascade from emission scenarios through climate models and hydrological models to impacts with particular focus on groundwater aspects for a number of coordinated studies in Denmark. The presentation provide examples of which sources of uncertainty dominates depending on context and purpose of study. In general, climate model uncertainty dominates for projections of climate change impacts on streamflow and groundwater heads. However, we find uncertainties related to geological conceptualisation and hydrological model discretisation to be dominating for projections of well field capture zones, while the climate model uncertainty here is of minor importance. The perspectives of reducing the uncertainties on climate change impact projections related to groundwater are discussed with particular focus on the potentials for reducing climate model biases through use of fully coupled climate-hydrology models.

## Climate-change effects on the epidemiology of infectious diseases and the impacts on Northern societies - an initiative from Nordforsk, Nordic centre of excellence

*Birgitta Evengård*

The main aim is to identify and investigate the effects of climate change on the geographic distribution and epidemiology of climate sensitive infectious diseases through the Nordic region and Russia. Particularly, CLINF will study such climate-change effects on northern animal husbandry households in the light of socio-economic and managerial conditions.

CLINF aims to turn new understanding, regarding climate-change effects on the geographic distribution and epidemiology of climate sensitive infections CSI, into practical tools for decision-makers responsible for the development of northern societies, both by providing relevant data in an accessible form, and by developing an early warning system for climate sensitive infections at the local level. CLINF will address the northern CSI scenario through a combined analysis of health statistics, potential landscape change and the associated CSI migration, perceptions of risk and societal cost, adaptive capacity to cope with risks and costs, and with strengthening societal CSI infrastructures. Adaptive capacity, gender effects, and traditional knowledge will, thereby, be used as integrating factors. The potential CSI effects of climate-change are dynamic and complex. The CLINF consortium therefore engages a multi-disciplinary team, with broad collaboration across science disciplines and societal stakeholders. CLINF rests on existing scientific and stakeholder infrastructures where, as an example, the existing network of northern environmental monitoring stations will be utilised to implement an early warning system for emerging infections at the local level. In addition, CLINF sets out to enhance the performance of regional Earth-process models regarding environmental climate-change effects, to develop methodologies for adequate assessment of societal risk and adaptive capacity, and to produce new map- and data products depicting the current and projected geographic spread of emergent CSIs. The results will be made accessible to scientists, stakeholders, and the public in accordance with OPEN principles, and will be disseminated in lay terms.



## Utilization of the ocean is dependent on decision support tools made possible by multidiscipline research collaboration

*Gunnar W Birkeland*

The maritime and marine industry have to adjust to more environmental friendly technology and operations and in the same time adjust to a changing climate.

The Norwegian based ocean industry has over the last years shown increasingly willingness to improve on their operations and there is multiple research, development and modification projects ongoing. The organizations have shown great capability in running and implementing the results of these improvements projects.

However, the technology development within tools for adapting to a changing climate need to get higher attention. Both the industry and the authorities are dependent on climate researcher together with other disciplines comes up with tools to help them make the right decisions.

More changing and extreme conditions increases the risk of failure and requires better decision tools.

In the same time, we do see that the marked, the industry and the authorities are more focused than ever before in utilizing the ocean to its optimal capacity. The need for decision support is obvious.

This topic and examples will be discussed in the oral presentation.

## Climate Services for business: A network of actors

*Kjersti Aalbu and Asun Lera St.Clair*

DNV GL Strategic Research & Innovation is maturing climate services for the private sector. In our theoretical work we are conceptualizing climate services as a network of actors that interact and influence each other in the production, translation, tailoring and use of climate information, tools and products. Recently, the need for co-producing climate services has been recognized by funders. The terminology of co-production of knowledge emerges from the social sciences. In our work in DNV GL co-production and co-design is a common way to work with our customers, to identify needs and produce new knowledge jointly with industry. We describe climate services as a network generating synergetic processes that can take multiple forms (e.g. collaboration, communication, translation) between the various actors involved where climate-related information is transformed and integrated into a specific user decision-making context. These ongoing interactions amongst actors should lead to climate services that are salient, credible and legitimate and that respond to the needs of those who use the services. Proper sector knowledge and understanding business needs is critical for a well-functioning of the network involved in the generation of climate services. This is critical for the emergence of trust in both the process and the outcome.

*Håvard Haarstad*

This presentation reflects on the role of cities and urban planning in climate transformations. The slow progress in international climate negotiations has shifted the attention of policy-makers and advocates towards cities and urban-level governments. Cities now appear to become a new locus of sustainability action and policy. Building compact, connected and livable cities is a critical part of climate and energy transformations. Further, it looks at governance challenges for sustainable planning, drawing on research from Norway and elsewhere. It is suggested that urban transformations require innovative and flexible governance arrangements that facilitate connections and collaborations between different actors and break down institutional 'silos'.

## Cities are key to solving the climate change challenge

*Jørgen Abildgaard*

In 2050 more than 2/3 of the global population will live in cities. The middle class will increase from 1.8 billion people in 2010 to around 5 billion people or more than half of the global population in 2030. This increase will first of all be in cities in South East Asia, Africa and South America. We will see massive investments in new infrastructure; energy, transport and buildings in those cities as a result of the growth in population. Planning and investments need to be sustainable and climate friendly, and take into account both investments in climate adaptation and climate mitigation otherwise it will be impossible to solve the global climate problems.

Therefore sustainable solutions in cities are the backbone for changing future investments in cities and many cities and companies already have a catalogue of solutions.

The UN climate meeting in Paris in December 2015 paved the way to make it possible.

## Climate change adaptation, infrastructure and land use – the importance of collaboration

*Per Sanderud*

A warmer and wetter climate will lead to more floods, an increased risk of landslides, sea level rise and flooding caused by storm water runoff. The expected changes entail a need for continuous adaptation to prevent unwanted incidents that may endanger human life and affect critical infrastructure such as power supply and transportation. Norway has started and is further preparing to handle the effects of climate change. The Norwegian Water Resources and Energy Directorate (NVE) has instruments that separately or in combination are suitable to provide climate adaptation in collaboration with other national, regional and local public and private actors.

The rate of climate change will vary, and the impacts will be different throughout the country. NVE's decisions have different time horizons. NVE has developed a climate change adaptation strategy that reflects this by being dynamic and adaptable to new knowledge. Climate change adaptation at NVE includes both producing increased knowledge about climate change as a sound foundation for decisions, as well as land use planning, hazard mapping and physical measures designed to prevent damages from flood and landslides. We have improved the knowledge basis through updated hydrological projections, flood analyses, and other work in collaboration with the Norwegian Centre for Climate Services (NCCS).

Changed inflow to hydropower reservoirs can increase hydropower production, if good decisions are made. This is one example of potential advantages of climate change. Expected changes in the 200-year flood may have severe negative consequences. Adaptation in this respect is to incorporate how to handle more frequent and larger floods in the guidelines for flood estimations related to dam safety, land use planning and infrastructure design. Important knowledge has also been produced in collaboration with the Norwegian road and railroad authorities in the project NIFS (Natural hazards, infrastructure, floods and landslides). In particular sharing of data and information and mutual capacity building led to optimisation of resources and development of efficient adaptation measures. At NVE, relevant knowledge has been integrated in guidelines. For example, how to consider climate change is described in the "Dam safety guidelines", and how to include climate change adaptation in land use is described in the guideline "Floods and landslides in land use planning".

The climate projections do not provide a clear-cut answer, as there is uncertainty attached to them. In particular, we need to meet challenges related to more frequent short duration extreme rain and rapid onset flooding. Relevant and improved cost-benefit studies could assist in prioritising optimal adaptation measures and illustrate the benefit of prevention. Therefore, more knowledge is required as is collaboration to develop and implement climate change adaptation measures.

## Adaptation to climate change and decision-making under uncertainty

*Suraje Dessai*

It is increasingly recognized that adaptation to climate change has become unavoidable. It is the only response available for the impacts that will occur over the next several decades before mitigation measures can have an effect. Societies, organisations and individuals have been adapting to changing conditions for centuries but the advent of climate change brings new challenges. Some of the challenges are brought about by issues related to the rate (and magnitude) of change of climate, the potential for non-linear changes and the long time horizons. All these issues are plagued with substantial uncertainties, which makes anticipatory adaptation difficult. The fact that we have partial knowledge of future climate is in itself a new challenge. Effective communication between science and policy - necessary for well informed adaptation policy making - is often hampered by misunderstandings about the phenomenon of uncertainty in the science. The focus on statistical and quantitative methods of uncertainty assessment leads to a tendency to ignore policy relevant uncertainty information about the deeper dimensions of uncertainty that in principle cannot be quantified. Lack of systematic attention for unquantifiable uncertainties in the science makes the perceived scientific foundation basis of climate policies prone to controversies, can undermine public support for climate policies, and increases the risk that society is surprised by unanticipated climate changes. This talk reviews methods and tools of uncertainty management and decision-making under uncertainty that can help inform adaptation decisions in both developed and developing nations.

## Pushing climate projections towards decisions: a somewhat bumpy road

*Luca Garrè*

Decision makers, engineers, and practitioners at large from various industrial sectors will have to consider projections of climate change in their current design, management, business practices and standards. This is a fundamental prerequisite for long-term sustainability and safety, which holds particularly true for investments in - and operations of - large, capital-intensive infrastructures. However, when placed in the usual decision making contexts faced by industries and the societies, the incorporation of climate projections can turn out to be rather onerous: conflicting estimates, ambiguous importance of uncertainties, operational constraints all give rise to a number of decision making challenges. Drawing from a number of analyses and case studies carried out within the Nordic region and beyond, this talk examines some of the challenges met while attempting to make sensible decisions on climate projections.

## Robust decisions for managing climate risks in Sweden

*Annika Carlsson Kanyama, Per Wikman Svahn, Jonathan Metzger, Misse Wester and Karin Mossberg Sonnek*

Planning and implementation of preventative measures relating to climate change requires the major uncertainties inherent in risk assessments relating to natural disasters and extreme weather events, and how these might change over time, to be considered. Uncertainties relating to changes in society must also be taken into account, including how vulnerabilities are altered and affected by complex dependencies between different systems and parts of society (e.g. indirect effects of climate change). If these uncertainties are not managed in a smart way, they could result in significant economic costs or increasing risks of accidents and disasters. One smart approach is to make more robust decisions, i.e. decisions that have acceptable results with respect to various potential outcomes and that avoid excessively costly or catastrophic outcomes. Robust decisions also encompass flexible or adaptive solutions, e.g. delaying costly or far-reaching decisions until more is known about how the uncertainty is developing. Robust decisions generally contribute to increased resilience, i.e. the capability to resist and resolve disruptions, recover and maintain and improve essential functions. Internationally, robust decision making approaches are increasingly being applied in different areas, including flood risk management in New York, London and the Netherlands and freshwater resources in California and Lake Superior. In Sweden, robustness is stated as an important goal in recent regional climate adaptation plans. Moreover, recent reviews of the current status of adaptation to climate change in Sweden highlight the need for better understanding and management of uncertainties and the potential of robust decision making in Sweden.



## Climate adaptation decision making in uncertain environments: the need for new ways of interfacing science and governance

*Jeroen P. van der Sluijs*

In the coming decades, climate change will pose considerable adaptation challenges to present day societies, requiring knowledge to be deployed in new ways. The Intergovernmental Panel on Climate Change (2014) concluded that responding to climate-related risks involves decision-making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation. In order to enable timely anticipatory and proactive adaptation, society needs to learn to utilise unavoidably imperfect knowledge from (climate) science on the deeply uncertain future changes in key climate variables; including precipitation patterns, heatwave frequencies, extreme weather events, spatial distribution of species, and rising sea levels. The uncertainties involved impede the decision making process that should lead to interventions in vulnerable sectors and subsystems (nature areas, agriculture, urban environment, infra structures, etc.) that add to the capacity of its major functions to withstand shocks and are able to adapt to gradual changes. Community-centred and resilience-based adaptation demands critical research and innovation regarding the institutional and societal cultures that underlie the way society mobilises knowledge in support of climate adaptation at the interfaces between science and policy and science and society.

## Climate change adaptation: the Nordic countries in a global perspective

*Richard Klein*

In large parts of the world, climate change is a matter of life and death. In the Nordic region, it is at worst an inconvenience and at best a boon. Thus was the conventional wisdom, explaining the complacency about climate adaptation that Karin O'Brien and colleagues described in *Ambio* ten years ago. Destructive floods, windstorms, landslides and wildfires have since revealed climate risk beyond reduced snow security for cross-country skiing. As a result, domestic adaptation is now a political priority in the Nordic countries, although a gap remains between planning and action. To provide support for adaptation in developing countries has also long been a Nordic priority. Less attention, however, is given to two other ways in which the Nordic region is connected to the rest of the world: how climate impacts elsewhere could indirectly affect Nordic people and business, and how Nordic consumption patterns could put other countries at higher risk of climate change. In this keynote I will discuss these three adaptation interdependencies between the Nordic countries and the rest of the world: adaptation finance, indirect impacts, and consumption-driven vulnerability.

## Approaching Adaptation through Transformation: Can Future Earth Make a Difference?

*Karen O'brien*

Climate change introduces unprecedented challenges to society, both in terms of impacts, social vulnerability and responses. Over the years, the global change research programs have contributed significant knowledge about climate change responses, especially on how to reduce risk and vulnerability through mitigation and adaptation. There have been discussions about mainstreaming adaptation into all sectors of society, including overseas development aid and urban planning, and climate change adaptation is now considered a necessary part of many decision-making processes. Yet adaptation involves more than complying with or adjusting to impacts that are already occurring or expected to occur; a more progressive interpretation of adaptation through transformation has been evolving. In this talk, I will consider the relationship between adaptation and transformation in the context of Future Earth, and discuss why transformations in both science and society may represent the most successful adaptation to climate change.

## From climate research to society: Examples from the North Sea

*Corinna Schrum, Frauke Feser, Insa Meinke and Ralf Weisse*

Climate change is a matter of concern for society and needs to be taken into account for policy and adaptation measures. Potential future impacts are regional and local and require adaptation measures, which ideally are based on a solid knowledge base taken into account current state of the art about climate change impacts and its uncertainty. However, the societal and political discourse is often spoiled by conflicts of interest and medial constructions of climate change, scientific knowledge is widely scattered and scientific evidence is difficult to assess. Scientific agreement or disagreement is typically not documented on regional scales, and sources of uncertainty are often difficult to identify and understand. Current understanding of local climate change impacts originates from a combination of observational based evidence and climate projections, both coming with specific limitations. Long term observations are often unavailable or inconsistent and their potential for extrapolation into the future is undetermined. Model based climate change projections on the other hand are based on a wide range of assumptions and subject to uncertainty. Moreover, climate change impacts on regional and local scales are often complex and depend on site-specific characteristics and the level of detail required to serve adaptation needs is often not available or difficult to extract from aggregated climate change scenario assessments. We will illustrate different aspects of these challenges and elaborate the added value of a combination of both climate information sources. Transferring, synthesizing and detailing the knowledge from science to society is a challenging task and requires different forms of communication, some examples from the North Sea and Northern German coast will be presented.

## Applying a new global scenario framework for investigating uncertainties in regional impact and adaptation studies

*Timothy R. Carter*

Following the publication of the IPCC Fourth Assessment Report in 2007, a process began to develop a new set of integrated scenarios describing future climate, societal, and environmental change for use in climate change analysis (Moss et al., 2010). The process began with the development of representative concentration pathways (RCPs) describing a set of four alternative trajectories of atmospheric composition and land use change (van Vuuren et al., 2011) suitable for use as forcing factors for global climate model simulations such as those conducted in the Climate Model Intercomparison project (CMIP - Eyring et al., 2016). At the same time, other work has focused on producing a set of five shared socioeconomic pathways (SSPs), which are alternative trajectories of future socioeconomic development that are defined both in narrative form (O'Neill et al. 2015) as well as being quantified using integrated assessment models. Using a conceptual framework recently constructed by the research community (O'Neill et al., 2014), SSPs and RCPs can be combined to form integrated scenarios that are designed to span a relevant range of uncertainties in climate and socioeconomic development so that they are suitable as input to impact, adaptation and vulnerability (IAV) studies.

This presentation describes recent progress in applying this scenario framework for studying regional impacts and adaptation in case studies at different spatial scales as part of the European Commission FP7 IMPRESSIONS project ([impressions-project.eu/](http://impressions-project.eu/)). This project is focusing on the implications of high-end scenarios, defined as scenarios associated with future global mean temperature change well in excess of 2° C above pre-industrial levels, which is a realistic outcome of unchecked increases in emissions of greenhouse gases into the atmosphere. The 2° C level has been used as a policy target by the United Nations Framework Convention on Climate Change for avoiding severe impacts, while the UNFCCC Paris agreement in December 2015 is more ambitious still, striving to pursue efforts to limit the temperature increase to 1.5° C. Such low-end scenarios are also considered in IMPRESSIONS for comparative purposes.

A number of novel approaches have been deployed for translating the global RCP/SSP framework into a set of workable and credible scenarios for each case study, which have been co-produced with local stakeholders. These scenarios are being applied as inputs to sector-based and cross-sector models for examining their potential impacts during the 21st century, for assessing the effectiveness of adaptation options for reducing vulnerabilities and, in combination with qualitative analysis and stakeholder dialogue, for exploring new policy approaches for adaptation, mitigation and sustainable development.

The following limited set of four RCP/SSP combinations has been selected for the IMPRESSIONS project: (i) SSP 1/RCP 4.5; (ii) SSP 3/RCP 8.5; (iii) SSP 4/RCP 4.5; and (iv) SSP 5/RCP 8.5, which after input to impact models allows for the following dimensions of uncertainty to be investigated:

- Regional climate changes (across RCPs and climate models)
- Socio-economic developments (across SSPs), defined with respect to challenges to adaptation and mitigation
- Impacts (both structural and parameter uncertainties of the models applied)

Initial impact results have been reported for some case study regions across the scenarios, The presentation will illustrate some of the regional scenario development outcomes and preliminary impact model results along with associated uncertainties. The intention is to compare these outcomes to stakeholder visions of the types of conditions they would wish to see in the study region.

## References

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## Cities are key to solving the climate change challenge

*Jørgen Abildgaard*

In 2050 more than 2/3 of the global population will live in cities. The middle class will increase from 1.8 billion people in 2010 to around 5 billion people or more than half of the global population in 2030. This increase will first of all be in cities in South East Asia, Africa and South America. We will see massive investments in new infrastructure; energy, transport and buildings in those cities as a result of the growth in population. Planning and investments need to be sustainable and climate friendly, and take into account both investments in climate adaptation and climate mitigation otherwise it will be impossible to solve the global climate problems.

Therefore sustainable solutions in cities are the backbone for changing future investments in cities and many cities and companies already have a catalogue of solutions.

The UN climate meeting in Paris in December 2015 paved the way to make it possible.