

Regional Climate Studies

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Markus Quante  
Franciscus Colijn *Editors*

# North Sea Region Climate Change Assessment

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# Regional Climate Studies

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The North Sea region as seen from satellite on 16 April 2003. *Sensor* Terra-Modis. *Credit* Jacques Desclotres, MODIS Rapid Response Team, NASA/GSFC; Saharan dust signals have been removed

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Editors

# North Sea Region Climate Change Assessment



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## Foreword

Climate change is a major threat for the 21st century and beyond as recognised by the world's governments who have funded the five assessments of the Intergovernmental Panel on Climate Change (IPCC) and numerous special reports since the 1980s. These efforts have been important in supporting global climate policy, culminating in the recent Paris Agreement on reducing future greenhouse gas emissions. In contrast, adaptation happens on smaller scales than climate mitigation and very different and more detailed information is required to support such decisions. A number of regional and local assessments have been produced with these issues in mind. As examples, in North America there have been several national assessments of the implications of climate change as well as city level studies such as for New York. In Europe there have been assessments at the EU scale such as the ACACIA and CLIMSAVE projects, the Baltic Sea region, national assessments such as the Delta Commission in the Netherlands, and city assessments such as for London and Hamburg.

The international North Sea Region Climate Change Assessment (NOSCCA) contributes substantial new insight into these efforts for the greater North Sea Region, constituting the first such assessment for this region. While North Sea societies have always faced climatic risk, the challenges are growing due to human-induced climate change mainly forced by enhanced greenhouse gas emissions, and often other significant non-climate drivers are in operation. At the same time, the available knowledge of climate change and its implications has expanded impressively over the past few decades. However, there is a challenge to synthesise and communicate this information in accessible and useful forms. The present assessment rises to these challenges to provide science-based information on climate change on the scale of adaptation decision-makers.

The independent and voluntary assessment team come from across the North Sea region. The component chapters have all been subject to extensive peer review and modification to promote wide and inclusive perspectives. Collectively, the chapters address a range of issues embracing climate science, ecosystems and socio-economics providing a unique integrated perspective which can support decision-makers and policy development. The authorship and editorship team are to be commended for their supreme efforts, establishing a platform for further assessments and updates as needed. The approach is readily transferable and might be transferred to other interested regions.

Robert J. Nicholls  
Professor of Coastal Engineering  
Review Editor for the North Sea Region Climate Change Assessment (NOSCCA)  
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## Preface

Climate change impacts show wide regional variability; their strength, nature and evolution depending on the principal features of the area in which they are occurring. To cope responsibly with its impacts, decision-makers and authorities need sound information on the specifics of climate change in their region. The science community would also benefit from a comprehensive analysis of the state-of-knowledge on regional climate change and its effects.

The North Sea region is a precious natural and cultural environment and a major economic entity within Europe. The North Sea is one of the world's richest fishing grounds as well as being one of the busiest seas with respect to marine traffic and its related infrastructure, oil and gas extraction is also of high economic value. More recently the area has become a major site for wind energy, with many large offshore wind farms. Climate change impacts are expected to have profound effects on North Sea ecosystems and economic development. Despite its importance, until now a comprehensive analysis of climate change and its impacts for the region as a whole had not been attempted. Some nationally-focused studies with an emphasis on climate change projections have been published in recent years, such as the UK Climate Projections—Marine and Coastal Projections and the KNMI'14 Climate Scenarios for The Netherlands to name but two examples,<sup>1</sup> and these have all been considered in the present study.

A few years ago, inspired by our colleague Hans von Storch, we initiated an international climate change assessment of the North Sea region. We adopted a similar approach to that successfully employed for reviews of knowledge on climate change in the Baltic Sea basin, published in 2008 and 2015.<sup>2</sup> This activity was named the North Sea Region Climate Change Assessment—NOSCCA—and has involved around 200 climate scientists in different research areas from all countries around the North Sea, as well as a few from more distant localities. NOSCCA developed into an independent international initiative, with all scientists involved contributing their time and effort on a voluntary basis as there was no extra funding available.

Present knowledge of climate change in the North Sea region has been evaluated mainly using peer-reviewed publications on climate change in the physical systems and its effects on land and marine systems. Two types of impact studies were envisaged: those concerning specific ecosystems and those related to specific human activities causing degradation of the environment.

After an introductory chapter on the North Sea region and its characteristics in terms of geography, geology, hydrography, present-day climate and ecology, Part I describes the climate change experienced over the past 200 years, described separately in each of three chapters on the atmosphere, the North Sea and river flow. Part II examines projections of

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<sup>1</sup>Lowe, JA, Howard TP, Pardaens A, Tinker J, Holt J, Wakelin S, Milne G, Leake J, Wol J, Horsburgh K, Reeder T, Jenkins G, Ridley J, Dye S, Bradley S. (2009) UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK; KNMI (2015): KNMI'14 climate scenarios for the Netherlands; A guide for professionals in climate adaptation, KNMI, De Bilt, The Netherlands, 34 pp.

<sup>2</sup>The BACC Author Team (2008), Assessment of Climate Change for the Baltic Sea Basin. Regional Climate Studies, Springer-Verlag, 473pp; The BACC II Author Team (2015) Second Assessment of Climate Change for the Baltic Sea Basin, Regional Climate Studies, Springer, 501pp.

future climate with separate chapters on the atmosphere, the North Sea, and river flow and urban drainage. The impacts of recent and future climate change on marine, coastal, lake and terrestrial ecosystems are presented in Part III. The report concludes with a consideration of climate change impacts on socio-economic sectors, Part IV contains chapters on fisheries, agricultural systems, offshore activities related to the energy sector, urban climate, air quality, recreation, coastal protection and finally coastal management and governance. Important background information is presented in five annexes to the report. An overall summary containing key statements from the different chapters precedes the main body of the book.

Climate change and its impacts on ecosystems has received much attention for many years. However, assessing the impacts of climate change on natural systems is far from straightforward. Environmental impacts resulting from non-climate drivers often make it very difficult to clearly establish the specific effects of climate change, which are already hard to attribute due to the difficulties of discriminating between natural variability and human interventions and their potential interactions. As a result, for many of the topics addressed in this assessment, other drivers have also been discussed, especially those that may mask potential climate change signals. Strict detection and attribution has not been undertaken here, mainly due to the lack of relevant published work. This could be the subject of a follow-up activity.

This assessment is a joint effort of 35 Lead Authors and a large group of contributing authors, who were willing to share their knowledge on many different aspects of the North Sea region and to contribute to compiling the different chapters. The process has been overseen by an international Scientific Steering Committee; the members are listed in the section ‘About NOSCCA’. A review phase involving a sovereign review editor and more than 60 external reviewers was crucial to establishing an independent and scientifically sound product. All authors worked without financial support for this book and were supported by their respective institutions. We are extremely grateful for their contributions. Authors and reviewers are acknowledged and listed by name on the following pages. The open access publication of this report was made possible by funds provided by various institutions, which are listed in the acknowledgements section.

We consider this assessment to be the most comprehensive study of climate change in the North Sea region to date. It is hoped that NOSCCA will be of use to decision-makers in the many countries surrounding the North Sea as well as to those who are responsible for planning and implementing climate change adaptation in the region. We hope this assessment will stimulate further monitoring and topical studies on climate change in this ecologically and economically important region of Europe and as a result will increase the effectiveness of decision-making at the local level.

Geesthacht, Germany

Markus Quante  
Franciscus Colijn



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# Acknowledgements

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## Book Production, Meetings, and Talks

A comprehensive and thorough assessment of climate change in the North Sea region would not be possible without the tremendous effort of many experts analysing regional climate change and its impacts and compiling dedicated topical chapters or reviewing manuscripts. Therefore, our thanks go primarily to the lead authors and contributing authors, who through excellent teamwork have produced the most comprehensive assessment of climate change in the North Sea region to date. We also thank the many reviewers, whose work has been crucial in ensuring the high scientific standard of this assessment report. Lead authors, contributing authors and disclosed reviewers are listed by name and institution on the following pages.

The entire review process was defined and overseen by an independent review editor. We are extremely grateful to Prof. Robert J. Nicholls of the University of Southampton, UK, for taking on and so competently accomplishing this important function.

The NOSCCA initiative was advised and supported, throughout the entire process, by an international Scientific Steering Committee (SSC), whose contributions are greatly appreciated. The members of the SSC are introduced in the section ‘About NOSCCA’ of this front matter.

Working efficiently with a large group of experts from many different institutes and countries in Europe profits from face-to-face exchange. Therefore several meetings of NOSCCA lead authors and members of the SSC were held during the writing and revision phases. The support—including financial—of some of our colleagues is greatly appreciated. Monika Breuch-Moritz of the Federal Maritime and Hydrographic Agency (BSH), Germany, hosted the first meeting of the SSC in close proximity to Hamburg harbour. The initial gathering of the NOSCCA lead authors together with the members of the SSC took place in the Royal Netherlands Academy of Arts and Sciences in Amsterdam. This meeting was made possible by Hein J.W. de Baar from the Royal Netherlands Institute for Sea Research and the University of Groningen, The Netherlands. The second lead author meeting took place in the Carlsberg Academy in Copenhagen, Denmark, and was arranged by Egil Kaas of the Niels Bohr Institute, Denmark. Jaap Kwadijk from Deltares, The Netherlands, arranged the third lead author meeting at the Deltares subsidiary in Delft. The final lead author meeting took place in the Chile House in Hamburg and was hosted by Daniela Jacob from the Climate Service Centre Germany of the Helmholtz-Zentrum Geesthacht.

The various topics of the envisaged climate change assessment were introduced during our meetings by invited keynote speakers. For their inspiring talks we thank Bas Amelung (Wageningen University, The Netherlands), Peter Burkill (Plymouth University, UK), Jens Hesselbjerg Christensen (Danish Meteorological Institute), Ken Drinkwater (Institute of Marine Research, Norway), Kirstin Halsnæs (Technical University of Denmark), Daniela Jacob (Climate Service Centre Germany), Albert Klein Tank (Royal Netherlands Meteorological Institute), Jaap Kwadijk (Deltares, The Netherlands), John K. Pinnegar (Centre for Environment, Fisheries and Aquaculture Science, UK), Marcus Reckermann (Baltic Earth),

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Producing such an extensive book is not possible without the technical support of particular individuals, to whom we are extremely grateful. Special thanks go to our colleague Ingeborg Nöhren; Ingeborg was deeply involved in technical editing, obtaining reproduction permissions and improving most of the many graphics. Graphical expertise was also provided by Beate Gardeike and Bianca Seth. Merja Helena Tölle, Marcus Lange, and Sabine Hartmann supported us in coordinating NOSCCA during its initial phase. Sönke Rau helped formatting the chapters. Insa Puchert conducted an actor analysis for the North Sea region. Thanks to Ina Frings for maintaining the NOSCCA homepage.

Last but by no means least, we thank Carolyn Symon (UK) for professional language editing and many useful editorial suggestions.

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## Open Access

To foster a wider outreach and to enhance the availability of our climate change review to young researchers and students, it was recently decided to release the NOSCCA report as an open access publication. This was made possible by shared funding with contributions provided by the following institutions and programmes: Cluster of Excellence ‘Integrated Climate System Analysis and Prediction’ at the University of Hamburg (CLISAP; Germany), Danish Meteorological Institute (DMI; Denmark), German Meteorological Service (DWD; Germany), Met Office (UK), Royal Netherlands Meteorological Institute (KNMI; The Netherlands), Swedish Meteorological and Hydrological Institute (SMHI; Sweden), Technical University of Denmark (DTU; Denmark), University of Bergen (Norway), and the Library and Institute of Coastal Research of the Helmholtz-Zentrum Geesthacht (Germany). Thank you very much for the essential support at short notice.

We sincerely hope that we have not forgotten anyone. Thank you so much to all of you for your tremendous effort and support, which together has made this assessment possible.

Geesthacht, Germany

Markus Quante  
Franciscus Colijn