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TELLUS

Preface

This special issue of Tellus is devoted to selected results arising from research in the project RegClim (Regional Climate Development under Global Warming) funded by the Research Council of Norway (RCN) under various programmes for climate-associated research.

The RegClim project was initiated in the fall of 1997 and it ended formally after three phases and 9.5 yr by ultimo 2006. It was the first multi-institutional RCN-project, and was in many ways organized similar to EU projects. The project would also be impossible without considerable computer resources provided through the Norwegian High Performance Computing Consortium for super computing.

The Norwegian Meteorological Institute co-ordinated the project. Throughout the 9.5 yr the other partners were Department of Geosciences at University of Oslo, Geophysics Department at University of Bergen, Nansen Environment and Remote Sensing Centre and Institute of Marine Research. For parts of the project period the Norwegian Institute for Air Research (1997–2002) and the Bjerknes Centre for Climate Research (2002–2006) participated. The project was managed by T. Iversen with S. Grønås and E. A. Martinsen as co-managers and M. Lystad as scientific secretary. The module leaders for the third phase (2002–2006) were E. Førland (Atmospheric downscaling), B. Ådlandsvik (Oceanic and coupled downscaling), N. R. Kvamstø (The role of the Nordic Seas) and J. E. Kristjansson / A. Kirkevåg (The role of aerosols).

There were on an average two all-staff meetings per year. International scientists were frequently invited to secure qualified criticism of the work. In the third phase, Professors U. Cubasch, (Free University of Berlin) and E. Källén (Stockholm University) were permanent and active scientific advisors for RegClim. Most of the presentations from the all staff meetings were preliminary printed in nine ‘General Technical Reports’, and many have later been developed and published. A considerable number of scientific papers from RegClim have thus been published, and many were referred to and used by Intergovernmental Panel on Climate Change (IPCC) in the third (TAR) and fourth (AR4) assessment reports, as well as in the report from the Arctic Climate Impact Assessment (ACIA).

RegClim was predominantly initiated for the purpose of producing data for anthropogenic climate change projections which enable further studies on the natural and societal impacts. The main focus of attention was Northern Europe, adjacent sea areas and the Atlantic-European sector of the Arctic. The data should account for uncertainties in the projections and the thus associated risks. The uncertainties should stem from choice of methods for data generation and choice of global climate projection. RegClim also emphasized particularly uncertain processes in the climate system, in particular those that cause warm and ice-free Nordic and Barents Seas, and the interactions of aerosols and climate. The project should expand and develop the existing Norwegian research competence.

Evaluation of potential natural and societal impacts of climate change projections will in many cases depend on weather-related data with higher spatial resolution than produced by present-day global climate models. Extreme weather events are, for example, often associated with meso-scale dynamical phenomena or even finer. A link between the global information and the methods to evaluate impacts is usually provided by downscaling of the global climate projections and partly by some upscaling of the methods for impact evaluation.

In RegClim both empirical downscaling and dynamical downscaling were applied. Empirical downscaling is based on fitting statistical relations between analysed atmospheric features resolvable by global climate models and observed local climate statistics. These relations are then applied to future model calculated projections of the resolved features. Once calibrated, the method is computationally cheap and can be quickly used to produce a wide range of local projections from available global datasets, assuming that the empirical relations are conserved as climate changes and that global climate models reproduce the synoptic features sufficiently accurate. The results are strictly valid only on observation sites for which there are sufficiently long and quasi-homogeneous time series, and the method relies on somewhat arbitrary choices of the synoptic features and the chosen type of statistical relationship. Numerous papers on the methodology and results of empirical downscaling at locations in Norway and in the Arctic have been published in RegClim, but none in this special issue.

Dynamical downscaling uses numerical model tools based on prognostic equations for selected portions of the climate system with results from global climate projections as driving conditions. In RegClim we mainly used regional models on limited domains with open lateral boundary conditions for the atmosphere (HIRHAM4) and for the selected ocean areas (ROMS). For atmospheric downscaling the global information is introduced

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through the open lateral boundaries and the sea-surface temperature and ice-cover. The land-surface is allowed to adjust to the atmosphere through an on-line land-surface module. For oceanic downscaling the global information is provided through open lateral boundary conditions and atmospheric forcing on top of the ocean surface. Also a model which couples the atmospheric processes with oceanic and sea-ice processes has been developed, and was tested on re-analysed data (ECMWF ERA) but has so far not been used for downscaling. Dynamic downscaling produces three-dimensional climate statistics in a given region based on the same type of methods as employed by global climate models. The method is principally consistent with laws of nature and depends less on arbitrary assumptions than empirical downscaling. One exception is the introduction of open lateral boundary conditions which raises questions as to what extent the method is formally well posed, and the method is technically more challenging and computationally more expensive. The added value of pure atmospheric or oceanic downscaling is also limited in areas where coupled processes are important, such as in the Arctic where sea-ice is a strong feedback agent.

In this special issue three papers discuss or present results using dynamical downscaling. Basic issues regarding atmospheric downscaling are addressed by 'perfect model' experiments, such as choosing a size of the domain for the regional model that maximizes the value added to the driving global data. Regional atmospheric climate projections are presented based on a combination of downscaled results from several global models using similar scenarios for anthropogenic radiative forcing. First results for oceanic downscaling of climate projections in the North Sea are presented as well, but only for a single estimate of future global climate (BCM with SRES A1b). Two papers show studies of immediate impacts based on dynamically downscaled climate scenarios for the atmosphere. These address changes in extreme sea state (waves and storm surge), and hydrological consequences of climate change on river runoff for selected watershed basins.

Some of the dynamically downscaled global climate projections for the atmosphere reflect uncertainties in the meridional overturning in the North-Atlantic Ocean (AMO). These global calculations are made with the Bergen Climate Model (BCM), which is a global coupled climate model to a large extent developed in RegClim. Basic validations of this model as well as analyses of results have been published in numerous papers earlier, and BCM was one of the global climate models that produced results for the IPCC AR4. This model calculates an AMO that is amongst the least sensitive to anthropogenic greenhouse gas forcing, and it is believed that this is partly a consequence of using an isopycnic ocean model (MICOM) that helps identifying water masses. A predicted freshening of the surface waters in the Northern North-Atlantic is compensated by increased northward transport of more saline surface waters due to increased surface winds and increased net evaporation in the subtropics. With the CMIP2 scenario (1% increase in CO_2 concentrations until doubling after ca. 70 yr), the AMO in BCM is estimated to reduce by 5–15% when double CO_2 levels are reached, which is less than calculated by many other IPCCmodels. The largest decrease is found for scenarios started from a phase with a relatively strong AMO and vice versa. A considerable reduction is calculated in the Arctic sea ice in all seasons.

The interaction of aerosols with climate through direct scattering and absorption of solar radiation, and indirectly by changing the microphysical and optical properties of clouds, was an important part of RegClim. The reason for this is partly the strong regional nature of the aerosols compared to most greenhouse gases, and partly that this was (and indeed still is) amongst the most important problem areas in anthropogenic climate change research along with radiative cloud feedbacks. Based on imported global model codes from the US National Center for Atmospheric Research, new schemes for aerosol life-cycling and aerosol physical properties have been implemented and studied. The most recent version of this model is named CAM-Oslo, which is an atmospheric GCM coupled to a land-surface module. Several papers have been published on this subject, and through an international intercomparison project (AeroCom) results have been provided to and used by IPCC AR4. This issue includes two papers based on the most recent development and one paper on extensive experiments with the former model version. The aerosol scheme includes major natural aerosol components and their interactions with clouds and radiation. It is run both in a stand-alone version with a prescribed ocean state, and for estimates of equilibrium climate response coupled to a slab ocean model. At present the focus is still on major challenges, in particular on natural aerosols and their influence on the size and properties of the anthropogenic, and how the aerosols influence cloud properties and the hydrological cycle. Results from CAM-Oslo coupled to a slab ocean are amongst the dynamically downscaled projections.

The remaining papers deal with different aspects of the extratropical general circulation of the atmosphere during climate variations and change. The first of these is a theoretical study of optimal forcing perturbations for generating state transitions towards the cold-ocean-warm-land flow regime. The non-linear dynamical perspective of climate change postulated in a number of papers by T. N. Palmer is discussed in this context and is partly confirmed. The work is done with the ECMWF model, with ERA data, and in co-operation with their staff and with staff at KNMI.

The other papers study extratropical storm tracks and their relations with large-scale flow regime patterns in the Northern Hemisphere. The main bulk of the work is based on reanalysed data (NCEP) and a tracking algorithm. In one of the papers the thus obtained storm track statistics is compared with the results from the Arpege atmospheric GCM, which presently is the atmospheric component of BCM, with analysed SSTs. Results are discussed with respect to seasonal variations and storm frequency, strength and clustering, as well as atmospheric transport of moisture. Arpege reproduces main features of the observed storm tracks, but several shortcomings are seen such as underestimates of the number and variance of cyclones and cyclone clustering in the Atlantic jet exit region.

The legacy of RegClim is considerable. The project has managed to focus research and development on models for anthropogenic climate change, and has triggered much activity in the research on impacts, consequences, and adaptation. More specifically RegClim leaves*, inter alea*:

– Research results, for example, as documented in more than 75 papers in the peer-reviewed literature since 2003 and contributions to IPCC and ACIA;

– Strong research competence in central fields in the modelling of natural climate variability and climate change, such as global climate modelling and empirical and dynamical downscaling, as well as on important processes in the climate system, such as ocean currents, sea-ice, aerosols and clouds;

– Huge amounts of data on regional climate change in Northern Europe available to anybody, for example climate impact scientist;

– Important contributions to popularization of the climate research through regular publications in the popular climate journal Cicerone (predominantly in Norwegian; now 'Klima'), in three brochures, in press conferences and in numerous talks, interviews and newspaper articles.

RegClim is presently followed up by a new project, NorClim, with many similar activities. The research is also strengthened by synergy with a number of other projects, for example financed through EU. One aim in the new project is to merge several of the activities in RegClim by developing common model tools aimed for addressing earth system studies.

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