Vol. 64: 3–6, 2015
doi: 10.3354/cr01313

CLIMATE RESEARCH
Clim Res

Published June 17

Contribution to CR Special 30 'Effects of extreme global warming in northern Europe'

INTRODUCTION

Effects of extreme global warming in northern Europe

Martin Drews[1], Jens Hesselbjerg Christensen[2]

[1]Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
[2]Danish Meteorological Institute, 2100 Copenhagen Ø, Denmark

ABSTRACT: In this *Climate Research* (*CR*) Special, the Centre for Regional Change in the Earth System (CRES) brings together scientific expertise (ranging from climate to social sciences) with practitioners and stakeholders to present thematic research addressing gaps in (1) our understanding of climate-system behaviour at a regional scale and in particular at the upper fringes of current climate scenarios; (2) what the effects of such changes might be; and (3) potential adaptations. CRES has developed a broad set of tools related to climate adaptation; this includes improved regional climate and hydrological models, impact models, integrated assessment models, economic models, decision support tools and spatial planning tools. Through a coordinated research effort these tools were applied to provide new information on climate, hydrology, nutrient dynamics, ecosystem responses and economic risks. The studies in this *CR* Special highlight potential effects of extreme global warming with a focus on Denmark and northern Europe.

KEY WORDS: High end climate scenarios · Climate change effects · Adaptation

1. BACKGROUND

The IPCC's Fifth Assessment Report (IPCC 2013b) assessed that the global mean surface temperature change at the end of the 21st century relative to the mean between 1850 and 1900 is 'unlikely (defined by the IPCC as a probability between 0 and 10%) to exceed 4°C for RCP2.6, RCP4.5 and RCP6.0 (high confidence) and is about as likely as not to exceed 4°C for RCP8.5 (medium confidence)' (p. 20). Since all of the RCP scenarios (Meinshausen et al. 2011) may be considered to be plausible, and do not have probabilities attached to them (IPCC 2013c), this actually implies that while the probability of 'extreme' global warming may be assumed to be low, a global mean surface temperature change exceeding even 4°C compared to pre-industrial levels cannot be ruled out based on the current state of knowledge. Beyond the 21st century, current climate projections suggest that it could be a question of when (not if) it will happen, should current levels of greenhouse gas emissions remain unmitigated. Fig. 1 shows the projected exceedance point in time (year) as a function of the 'exceedance global mean temperature' for the CMIP3 (Meehl et al. 2007) and CMIP5 (Taylor et al. 2012) models under different emission scenarios. The spread of the individual projections show that, beyond the year 2100, global warming levels on the order of 4°C or more are clearly achievable. For the past decade, however, the emphasis, both in terms of policy and science, has been on how to stabilize global greenhouse gas emissions at a level equivalent to a global mean surface warming 2°C above pre-industrial levels within the 21st century, with research projects frequently targetting 'middle-of-the-road' scenarios such as SRES A1B (Nakićenović & Swart 2000) and their implications. One might argue that this trend is im-

*Corresponding author: mard@dtu.dk

Publisher: Inter-Research · www.int-res.com

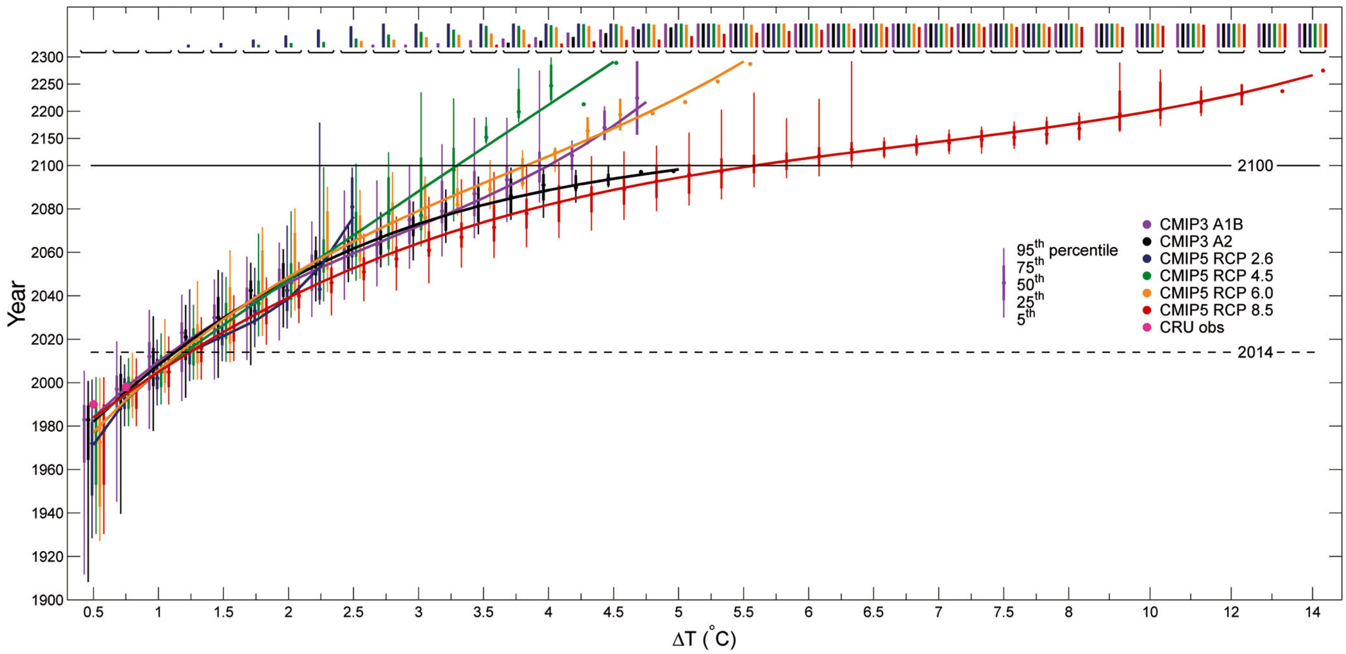

Fig. 1. 'Model year' where CMIP3 (Meehl et al. 2007) and CMIP5 (Taylor et al. 2012) climate projections reach a certain level of global temperature change (relative to the average of 1861–1880) as a function of that temperature change. The figure includes results for the A1B and A2 scenarios for CMIP3 and the 4 RCP scenarios for CMIP5. Observations represented by the HadCRUT.4.2.0.0 dataset (Morice et al. 2012) are shown for comparison as magenta dots. Individual vertical bars show the 5th, 25th, 50th, 75th and the 95th percentile of model years for the available models achieving the specific temperature increase. The top part of the figure shows the relative fraction of models not reaching higher temperature changes. It should be noted that both the *x*- and the *y*-axes are non-linear

plicitly continued even in the IPCC's Fifth Assessment Report where only results of the mitigated RCP4.5 scenario are displayed in the printed version of the 'Atlas' of projected temperature and precipitation changes forming part of the main volume (IPCC 2013a), although admittedly all 4 RCP scenarios are available as on-line supplementary material. Whether this is valid or not, extreme global warming scenarios and their possible implications have so far only been investigated sparsely and in a non-systematic way by climate and impact modelers (with a few notable exceptions, including New et al. 2011) as compared to mid-range scenarios.

2. IMPLICATIONS OF EXTREME GLOBAL WARMING

The implications of extreme global warming are not well known. For example, what is 'extreme' with regards to the functioning of specific ecosystems may vary greatly, and may differ in turn from what is regarded as extreme for societal systems. Adaptation to climate change generally requires a precise understanding and quantification of how human activities, interacting with natural processes, affect human and natural systems. The Centre for Regional Change in the Earth System (CRES) is a multidisciplinary climate research platform, which brings together leading Danish scientists—specialising in fields ranging from climate to the social sciences—with practitioners and stakeholders. This *CR* Special presents the results of thematic research carried out within CRES, which—similar to New et al. (2011)—aims at addressing some of the glaring gaps in our understanding of how the climate system might behave at the upper limit of current IPCC scenarios, what the effects of such changes might be and how to adapt to what would be unprecedented changes in the world we live in. From the CRES platform, a broad set of tools has been developed which can aid in the adaptation to climate, including improved regional climate, hydrological, impact, integrated assessment and economic models, and decision support and spatial planning tools. Through a coordinated research effort, these tools were applied to provide new information on climate, hydrology, nutrient dynamics, ecosystem responses and economic risks. In combination the different studies highlight issues related to extreme global warming with a focus on Denmark and Northern Europe.

3. CONTRIBUTIONS TO THIS *CR* SPECIAL

The Special is comprised of 7 studies. Rummukainen (2015) reviews our present commitment to climate change as compounded by climate system inertia and socio-economic trends such as investment patterns and climate policy. Grinsted et al. (2015) use existing climate projections for the high RCP8.5 scenario to estimate the 21st century relative sea level rise in Northern Europe, emphasizing that considerable uncertainties stem from the sea level budget, in particular when determining an upper bound and the regional expression of sea level rise. Complementary to this study, Christensen et al. (2015) use a global circulation model downscaled over Europe with the regional model DMI-HIRHAM5 to investigate whether regional climate changes generally scale with global temperature at 6°C of global mean warming. For most of the quantities examined, the pattern scaling approach they adopt seems to be valid for the 6°C simulation, indicating that the simulation is not an outlier and that conclusions therefore would probably correspond to conclusions drawn from multi-model ensemble simulations of such a scenario. In this context and using the climate scenarios from Christensen et al. (2015), Karlsson et al. (2015) and Trolle et al. (2015) have examined the influence of extreme climate change on the hydrology, and in turn the ecological state, of lakes in Denmark. Karlsson et al. (2015) find that the most prominent changes in water balance are due to the drying out of soils rather than precipitation effects, whereas Trolle et al. (2015) report on substantial lake eutrophication, which is strongly enhanced by external nutrient loading to the lakes. The issue of urban adaptation to climate change is addressed by Arnbjerg-Nielsen et al. (2015), who investigate whether the existing ambitious climate adaptation plan of Copenhagen will also account for projected changes in sea surge and precipitation under a 6°C scenario; Arnbjerg-Nielsen et al. find that if the plan is fully implemented (which will be an effort spanning several decades) Copenhagen will be well protected even in a high-end scenario, but also that it remains to be seen if the current polical awareness will endure. A related study by Halsnæs et al. (2015), using the Danish city of Odense as an example, discusses the importance of decision-maker assumptions with regards to adaptation at increasing levels of climate change, including the severity of climate impacts, damage cost curves and economic assumptions like risk aversion and equity.

4. PERSPECTIVE

This *CR* Special illustrates, in a consistent manner, how an extreme but not improbable future climate may unfold and challenge society and the management of natural and manmade systems. As depicted by the collection of studies, adaptating to climate change is not simply an issue of turning a knob gradually towards higher values. Several components of the climate and managed systems are non-linearly related, raising doubts about the preparedness of society to make necessary adjustments (based on current thinking and adaptation strategies) as they head towards potential high end, high impact scenarios. Overall, the tools available to assist adaptation planning are clearly not yet geared to address these non-linearities, nor the fact that climate change should be seen as a continuing process and not as a step function by which we need to adapt to a particular future. Instead, means to enhance resilience to the effects of climate change, including under more extreme scenarios, appear to be in demand. In this *CR* Special, the CRES underlines that in order to address these challenges, a holistic and coordinated multi- and even cross-disciplinary approach is absolutely necessary.

Acknowledgements. This work was supported by the Danish Council for Strategic Research under a contract for the Centre for Regional change in the Earth System (CRES) (contract no. DSF-EnMi 09–066868). The authors also gratefully acknowledge F. Boberg (Danish Meteorological Institute) for stimulating discussions and for carrying out the analysis depicted in Fig. 1, and the IMPRESSIONS project funded by the European Union's Seventh Programme (grant agreement no. 603416) for stimulating discussions.

LITERATURE CITED

Arnbjerg-Nielsen K, Leonardsen L, Madsen H (2015) Evaluating adaptation options for urban flooding based on new high-end emission scenario regional climate model simulations. Clim Res 64:73–84

Christensen OB, Yang S, Boberg F, Fox Maule C and others (2015) Scalability of regional climate change in Europe for high-end scenarios. Clim Res 64:25–38

Grinsted A, Jevrejeva S, Riva REM, Dahl-Jensen D (2015) Sea level rise projections for northern Europe under RCP8.5. Clim Res 64:15–23

Halsnæs K, Kaspersen PS, Drews M (2015) Key drivers and economic consequences of high-end scenarios: uncertainties and risks. Clim Res 64:85–98

IPCC (2013a) Atlas of Global and Regional Climate Projections. Annex I. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

IPCC (2013b) Summary for policymakers. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

IPCC (2013c) Long-term climate change: projections, commitments and irreversibility. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

Karlsson IB, Sonnenborg TO, Seaby LP, Jensen KH, Refsgaard JC (2015) Effect of a high-end CO_2-emission scenario on hydrology. Clim Res 64:39–54

Meehl GA, Covey C, Delworth T, Latif M and others (2007) The WCRP CMIP3 multi-model dataset: a new era in climate change research. Bull Am Meteorol Soc 88: 1383–1394

Meinshausen M, Smith SJ, Calvin KV, Daniel JS and others (2011) The RCP greenhouse gas concentrations and their extension from 1765 to 2300. Clim Change 109:213–241

Morice CP, Kennedy JJ, Rayner NA, Jones PD (2012) Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: the HadCRUT4 dataset. J Geophys Res 117:D08101, doi: 10.1029/2011JD017187

Nakićenović N, Swart R (eds) (2000) Special report on emissions scenarios. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge

New M, Liverman D, Schroeder H, Anderson H (2011) Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. Phil Trans R Soc A 369:6–19

Rummukainen M (2015) Our commitment to climate change is dependent on past, present and future emissions and decisions. Clim Res 64:7–14

Taylor KE, Stouffer RJ, Meehl GA (2012) An overview of CMIP5 and the experiment design. Bull Am Meteorol Soc 93:485–498

Trolle D, Nielsen A, Rolighed J, Thodsen H and others (2015) Projecting the future ecological state of lakes in Denmark in a 6 degree warming scenario. Clim Res 64:55–72

Submitted: June 11, 2014; Accepted: May 6, 2015

Proofs received from author(s): June 1, 2015