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A special issue on the RCPs

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Scenarios form a crucial element in climate change research. They allow researchers to explore the long-term consequences of decisions today, while taking account of the inertia in both the socio-economic and physical system. Scenarios also form an integrating element among the different research disciplines of those studying climate change, such as economists, technology experts, climate researchers, atmospheric chemists and geologists. In 2007, the IPCC requested the scientific community to develop a new set of scenarios, as the existing scenarios (published in the Special Report on Emissions Scenarios, (Nakicenovic and Swart 2000), and called the "SRES scenarios") needed to be updated and expanded in scope (see Moss et al. (2010) for a detailed discussion).

Researchers from different disciplines worked together to develop a process to craft these new scenarios, as summarized by Moss, et al. (2010). The Integrated Assessment Modeling Consortium (IAMC), founded in response to the IPCC call, played a key role in this process.[1] The scenario development process aims to develop a set of new scenarios that facilitate integrated analysis of climate change across the main scientific communities.

[1] http://iamconsortium.org/

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The process comprises 3 main phases: 1) an initial phase, developing a set of pathways for emissions, concentrations and radiative forcing, 2) a parallel phase, comprising both the development of new socio-economic storylines and climate model projections, and 3) an integration phase, combining the information from the first phases into holistic mitigation, impacts and vulnerability assessments. The pathways developed in the first phase were called "Representative Concentration Pathways (RCPs)". They play an important role in providing input for prospective climate model experiments, including both the decadal and long-term projections of climate change. The RCPs also provide an important reference point for new research within the integrated assessment modeling (IAM) community by standardizing on a common set of year-2100 conditions, and exploring alternative pathways and policies that could produce these outcomes. By design, the RCPs, as a set, cover the range of radiative forcing levels examined in the open literature and contain relevant information for climate model runs.

This Special Issue documents the main assumptions and characteristics of the RCPs, and, in particular, the various steps that were involved in their development. A number of collaborative activities were initiated and finalized during the last 2–3 years to develop the RCPs.[2] This required the cooperation of researchers from various disciplines involved in climate research, including emission experts, climate modelers, atmospheric chemistry modelers, land use modelers and experts involved in integrated assessment. The four RCPs together reflect the range of year-2100 radiative forcing values found in the literature, i.e. from 2.6 to 8.5 W/m^2. The papers in this Special Issue describe the individual RCPs, but also the various integrative steps that were necessary within the RCP development process to provide a harmonized set of pathways, that show a smooth transition from the past and extend far into the future for very long-term experiments. Important outcomes of this process included, for instance, the development of new emission inventories, new methods for the harmonization of spatial land use patterns, as well as extensions of the RCP trends beyond 2100. Below, we briefly discuss the content of the individual papers.

The first paper by Van Vuuren et al. (2011a) provides an overview of the RCPs. It discusses the expected attributes of the RCPs and the derived methodology. It also summarizes the main characteristics of the RCPs, comparing them among each other and with the overall literature for crucial parameters, such as emissions, concentrations, radiative forcing and land use. The paper goes on to discuss some important implications of the RCP characteristics for their use. The paper confirms that the RCPs cover the full literature range for greenhouse gas emissions and radiative forcing. As such, it concludes that the RCPs provide a unique spatially explicit data set covering the pre-industrial period up to 2100 (and extended to the period up to 2300). The paper also shows that, for land use and air pollutants, the RCPs need to be interpreted more carefully as here the linkages with the forcing levels are less direct (implying that many different air pollutant and land-use projections might be consistent with the RCP levels).

The papers on the individual RCPs by Riahi et al. (2011), Masui et al. (2011), Thomson et al. (2011) and Van Vuuren et al. (2011b) describe them in more detail (RCP8.5, RCP6, RCP4.5 and RCP2.6). These papers briefly discuss the modeling systems that have created each RCP, the main socio-economic assumptions, the underlying trends in energy use and details on emissions and land use. Moreover, the papers each present alternative scenarios that lead to forcing levels similar to the four "official" RCPs.

[2] The process began as a series of discussions in interdisciplinary meetings and gradually developed into a formal process. It is therefore not really possible to give a precise moment as the start of the process.

The paper by Hurtt et al. (2011) subsequently describes how the land use data of the individual modeling teams were harmonized and made consistent with the description of historical land use change obtained from the HYDE database. This was a challenging task as the land use descriptions of the four IAMs were very different (e.g. the spatial representation of the individual IAMs ranged from regional coverage to detailed dynamic projections at 0.5×0.5 degree grids). The paper describes the methods to convert the IAM data into one internally consistent set of spatial land projections (maps at 0.5×0.5 degree), including the development of additional land-cover products, such as transition matrices that describe in detail how different land use or land cover types are transferred to other forms. The paper also presents a detailed sensitivity analysis, indicating how major assumptions in the design process influence the results. All in all, this study for the first time harmonizes land-use history data together with future scenario information from multiple IAMs into a single consistent, spatially gridded set of land-use change scenarios for studies of human impacts on the past, present, and future earth system.

Next, the paper of Garnier et al. (2011) discusses the emission inventory used for the RCPs. The data requirements for the Earth System Models (ESMs) with respect to 1) number of species, 2) sectoral disaggregation, and 3) geographical scale (0.5×0.5 degree grid) implied that a new data set was needed to cover the 1850–2000 period. The paper compares the results from the RCP data inventory (constructed by combining existing inventories) to those from other inventories. This comparison shows large discrepancies between the different inventories for some species, indicating the need for further improvement to reduce uncertainties of past and present emission estimates.

The paper of Lamarque et al. (2011) combines the historical emission inventories and the RCP emission data to calculate future changes in ozone concentrations, aerosols, and nitrogen and sulfur depositions. The resulting concentration, forcing and deposition maps cover the full 1850–2100 period and indicate that ozone concentrations could develop differently, depending on the RCP examined. In particular, tropospheric ozone was projected to decrease in RCP2.6, RCP4.5 and RCP6 and increase in RCP8.5, between 2000 and 2100. Anthropogenic aerosol concentrations were projected to strongly decrease in the 21st century, a reflection of their projected decrease in emissions in all RCPs.

Finally, the paper by Meinshausen et al. (2011) discusses the harmonization of greenhouse gas emissions, concentrations and radiative forcing (based on a single set of observations applied to all the RCPs). It applies a single climate model to derive RCP concentrations and forcing levels. The paper also discusses simple rules that were applied to extend the RCPs beyond their time frame to cover the period from 2100 to 2300. This extension is useful to climate modelers interested in slow earth system processes, such as sea level rise. The extensions illustrate, among others, the inertia of the climate system to return from relatively high greenhouse gas concentrations to lower levels (one extension, for example, aims to reduce post 2100 forcing levels from 6 to 4.5 W/m^2).

Together, the nine papers provide a full documentation of the four RCPs. Further details of the RCPs can be found at the interactive RCP web based database[3] where historical and future data sets at different spatial resolutions are made available for downloading. The RCPs are an important development in climate research and provide a potential foundation for further research and assessment, including emission mitigation and impact analysis.

[3] http://www.iiasa.ac.at/web-apps/tnt/RcpDb/

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