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Contribution to CR Special 23 'Regional Climate Model evaluation and weighting'

Introduction

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ABSTRACT: An ensemble of regional climate models downscaling reanalysis data has been evaluated against observations for the time period 1961–2000. Various aspects of model performance including both their representation of large-scale features and their ability to add value on smaller spatial scales have been considered. A set of metrics has been derived and combined into a performance-based weigthing system that is used in the production of probabilistic climate change projections. Strengths and weaknesses of weighting techniques for RCM ensembles are discussed.

KEY WORDS: ENSEMBLES · RCM ensemble · Europe · Weighting scheme

Background

Detailed information about climate variability and change for future time periods can only be derived from climate models. Coarse-scale global climate models (GCMs) fail to represent important regional and meso-scale climate in detail. Regional climate models (RCMs), on the other hand, can operate at high horizontal resolutions, allowing for a more detailed representation of land–sea contrasts, vegetation cover and topography, and for a better representation of synoptic and mesoscale atmospheric processes. The technique of downscaling GCM results with RCMs therefore adds high-resolution detail to the regional climate, while preserving the large-scale features from the GCM (e.g. Rummukainen 2010).

In recent years a large number of RCM scenarios has been produced for simulation of the future European climate (e.g. Christensen & Christensen 2007, Déqué et al. 2005, 2007, van den Linden & Mitchell 2009). An important finding in these multi-model experiments is that climate change scenarios with different RCMs can differ significantly, even if the lateral boundary conditions are taken from the same GCM. This adds an additional level of uncertainty to the total uncertainty in regional climate change projections. Experience shows that different RCMs exhibit a wide range of performances in simulating climate variables and statistics, and no model outperforms the others in all aspects (Christensen & Christensen 2007, Jacob et al. 2007). These considerations provide strong grounds for using multi-model ensembles for deriving detailed climate change information at the regional scale. At the same time, the different performance by RCMs suggests that performance-based weighting schemes may be applied in the process of combining multi-model results, to increase the reliability of the projections (Giorgi & Mearns 2002).

RCM evalution and weighting

In the European project ENSEMBLES, a work package was devoted to designing and testing a weighting system for a multi-model ensemble of RCMs. This work is reported in this special issue. The construction of the weighting system was based on the performance of the RCMs in reproducing different climate characteristics of the recent past (ca. 1960–2000). For this time period 15 RCM experiments were conducted using reanalysis data (ERA40; Uppala et al. 2005) as (perfect) lateral boundary conditions. The RCMs are evaluated against different observed climate variables and statistics to ensure that the weighting system takes into account RCM performance for various aspects of regional climate. These aspects include measures of model ability in simulating large-scale features mostly determined by the lateral boundary condition forcing,

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but especially measures of added value over the large scale forcing model (GCM or reanalysis) for the domain in question. Therefore the weighting metrics were specifically designed for application to RCMs. Each group participating in the ENSEMBLES exercise assessed a different type of performance metric, so that a broad range of performance metrics was assessed. Then all the metrics were combined into a single model weight, which was used to produce probabilistic climate change projections based on the ensemble of participating RCMs.

Contributions to this Special

This CR Special includes the following studies, which describe and test individual performance metrics, the combination of the metrics into a single weight and the production of probabilistic change projections. Coppola et al. (2010) report on the RCM performance metrics in reproducing the observed meso-scale signal, i.e. the signal not resolved by the coarse-scale GCMs, in seasonal mean temperature and precipitation; this is therefore a direct added value metric. Kjellström et al. (2010) report on broad-scale performance over the entire probability distribution functions of simulated daily and monthly temperature and precipitation. An important aspect of added value in RCMs lies in their ability to better resolve extreme events. Within this context, performance metrics based on extremes in 24 h precipitation are assessed by Lenderink (2010). Simulated long-term trends in temperature are compared to different observational climatologies by Lorenz & Jacob (2010) as a measure of the model performance in simulating climate trends and changes. In addition to the contributions to this Special, Sanchez-Gomez et al. (2009) evaluated RCM performance in reproducing the large-scale circulation patterns given by the driving GCMs and Halenka et al. (unpubl.) assessed RCM performance in simulating the seasonal cycles of temperature and precipitation. These evaluation studies result in metrics between 0 and 1, with 1 denoting a perfect agreement with observations. Based on these separate performance-based metrics Christensen et al. (2010) describe how they can be combined into a single comprehensive weighting system with consideration of related uncertainties. Déqué & Somot (2010) show how these comprehensive weights can be used in the production of a probabilistic climate change projection based on the RCMs used in the ENSEMBLES project.

In a study focusing on wind storms and estimations of calculated loss, Donat et al. (2010) make use of insurance loss records as independent proxy data to evaluate the RCMs and demonstrate that an individual storm not well captured by the RCMs can lead to a deterioration of the ensemble results. They also discuss the effects of RCM ensemble composition and size. Another application of the RCM ensemble is given by Buser et al. (2010), who use a Bayesian methodology to combine climate change information from the multi-model ensemble into a single probabilistic projection.

Perspective

Performance-based weighting is subject to considerable debate as an approach for combining climate change information. As is necessarily the case with any weighting system, the one presented in this Special builds on a range of subjective choices concerning both the performance metrics and the procedure to combine them into an overall weight for each model. The spread between RCMs can easily be modified by giving higher/lower priority to certain weights or to redefine the individual metrics. This implies that climate change information building on weighted combinations of model results is dependent, possibly in a pronounced fashion, on the formulation of the weighing system. Therefore, a weighing system adds an additional level of uncertainty to the climate change scenarios that needs to be characterized and communicated in work on climate change guidance and subsequent impact studies. The work presented in this Special does not provide definite answers in the debate on weighting, but rather proposes approaches specifically designed for RCM application and discusses their advantages and limitations. This Special is intended to provide a foundation for a better understanding and use of weighting techniques.

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