The curse of the law of small numbers haunts regional climate modelling

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A. Background

High-resolution regional climate models (RCMs) are often used to downscale transient simulations from coarse global climate models (GCMs) in order to provide detailed descriptions of local climatic consequences of a global warming.

Due to high computational cost of RCMs, only a small subset of GCMs are downscaled. Although there are methods for making selections more or less objectively (e.g. McSweeney et al.), any small selection will give an incomplete representation of the natural variability. The small sample also makes the analysis of changes in extremes challenging.

The strength of RCMs is that they provide a complete picture of the atmosphere, and their value may be more optimized if they are used to downscale selective events (e.g. Meredith et al.) and provide scenario cases for specific types of events, such as periods with drought, excessive precipitation, inversion, city pollution, or typical storms.

B. Examples of biases from small samples

Example 1
Temperature change in 30 random samples of 4 GCMs from CMIP5 RCP 4.5.

Example 2
7 Euro-CORDEX GCM-RCM simulations (4 different GCM simulations) compared to empirical-statistical downscaling of the same GCMs as well as the full CMIP5 ensemble (108). Both GCM/RCM and GCM/ESD show fairly good agreement of a temperature increase over Norway, however, both the magnitude and spread based on the GCM subset are underestimated when compared to the full CMIP5 ensemble (ESD).

C. We suggest to

- combine RCM data with empirical-statistical downscaling (ESD) data for large multi-model ensembles.
- emulate the RCMs by using statistical methods and large multi-model ensembles to simulate the local response.
- use RCMs to statistically downscale selective events.

Key points

- Ensembles made from a small number of GCMs may give large biases in certain measures.
- The effect of different GCM-RCM combinations depends on the GCMs’ description of the regional climate as boundary conditions.
- Traditional use of regional climate models has limited value for climate change adaptation to extreme events.
- This limitation does not vanish, even if the GCMs and the RCMs were perfect models. The law of small numbers is a fundamental limitation.

References

