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

Rasmus Benestad, Oskar Landgren, Abdelkader Mezghani, Helene B Erlandsen,
Andreas Dobler, Julia Lutz, Kajsa Parding and Jan Erik Haugen
Model and climate analysis, Norwegian Meteorological Institute, Norway (oskar.landgren@met.no)

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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.

A. Background

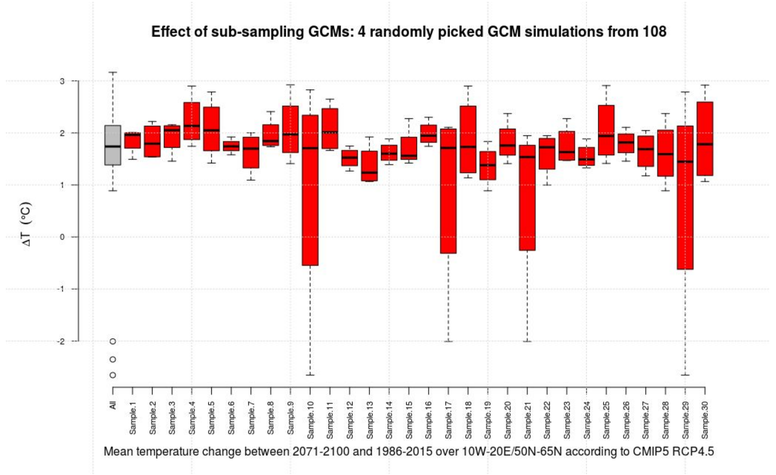
High-resolution regional climate models (RCMs) are often used to downscale transient simulations from coarse global climate models (GCMs) in order to provide detailed descriptions of local climatic consequences of a global warming.

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 RCP4.5.



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).

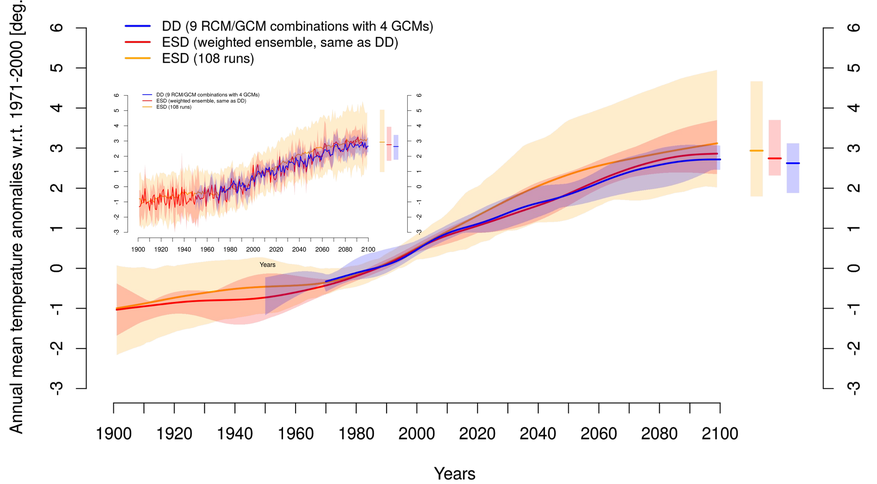


Figure caption: Modeled regional temperature (°C) anomalies by the common subset of global climate models, i.e. GCMs used in the Euro-CORDEX simulations (red envelope) and the full set of CMIP5 global climate models (yellow envelope) assuming RCP4.5 emission scenario. All simulation are smoothed with a ten-year moving average. The boxplots show the average over 2071-2100 based on the actual 5th and 95th percentiles, i.e. without smoothing.

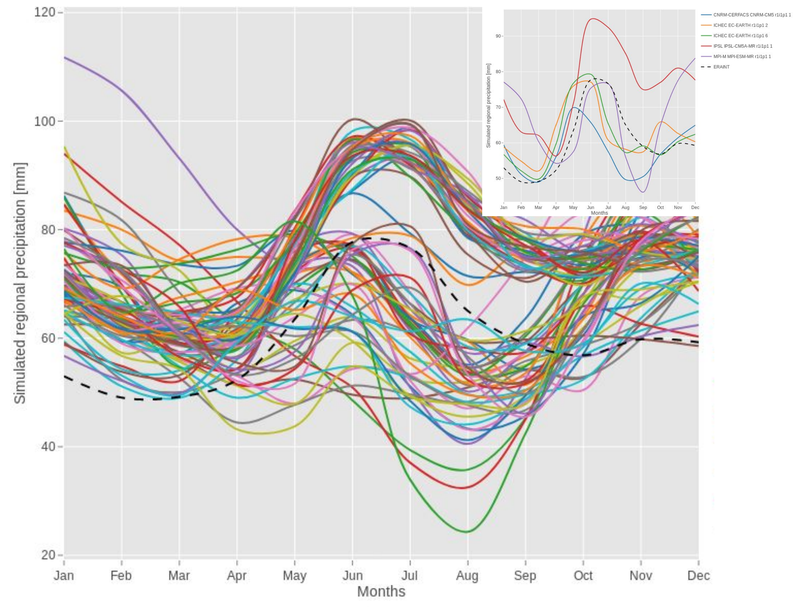


Figure caption: Annual precipitation cycle [mm/month] for Central Europe 1981-2010. Main plot: CMIP5 GCMs. Insert: selection of 5 GCMs used in Euro-CORDEX. The dashed line show estimates from reanalysis. The plots have been produced through the interactive platform of CMIP5 global climate model simulations publicly available at https://climatedatasite.net/

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.

References

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Meredith, E. P., Rust, H. W., and Ulbrich, U.: A classification algorithm for selective dynamical downscaling of precipitation extremes, Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-660, in review, 2017

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