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Comparing inter-annual variabilities in three regional single model initial-condition large ensembles (SMILE) over Europe

Fabian von Trentini[1], Emma E. Aalbers[2,3], Erich M. Fischer[4], and Ralf Ludwig[1]

[1]Ludwig-Maximilians-Universität München, Department für Geographie, München, Germany (fabian.trentini@lmu.de)
[2]Royal Netherlands Meteorological Institute (KNMI)
[3]Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam
[4]Institute for Atmospheric and Climate Science, ETH Zurich

Single model large ensembles are widely used model experiments to estimate internal climate variability (here: inter-annual variability). The underlying assumption is that the internal variability of the chosen model is a good approximation of the observed natural variability. In this study, for the first time over Europe, we test this assumption based on the comparison of three regional climate model large ensembles (16 members of an EC-EARTH-RACMO ensemble, 21 members of a CESM-CCLM ensemble, 50 members of a CanESM-CRCM ensemble) for four European domains (British Isles, France, Mid-Europe, Alps). Simulated inter-annual variability is evaluated against E-OBS and the inter-annual variability and its future change are compared across the ensembles. Analyses comprise seasonal temperature and precipitation, as well as indicators for dry periods and heat waves. Results show a large consistency of all three ensembles with E-OBS data for most indicators and regions, validating the abilities of these ensembles to represent natural variability on the annual scale. EC-EARTH-RACMO shows the highest inter-annual variability for winter temperature and precipitation, whereas CESM-CCLM shows the highest variability for summer temperature and precipitation, as well as for heatwaves and dry periods. Despite these model differences, the sign of the future changes in internal variability is largely the same in all models: for summer temperature, summer precipitation and the number of heat waves, the internal variability increases, while it decreases for winter temperature. While dry periods reveal a tendency to increase in variability, the changes of winter precipitation remain less conclusive. The overall consistency across single model large ensembles and observations strengthens the concept of large ensembles, and underlines their great potential for understanding and quantifying internal climate variability and its role in climate change dynamics.