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The influence of large-scale lapse-rate changes on the European summer climate

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The record-breaking summer heatwaves in 2003 and 2010 had large socio-economic impacts. Over recent decades a strong increase in European summer temperatures has been observed especially in the uppermost percentiles. Future climate projections provide strong evidence for this trend to continue. However, the processes driving the observed and projected changes in European summer climate and climate variability are not fully understood. Different mechanisms were proposed including changes in soil moisture regime, cloud-cover changes or altered large-scale circulation patterns. So far, only few studies considered the regional feedbacks of a large-scale lapse-rate change.
In the present study we apply the surrogate climate change technique to regional climate model simulations to disentangle this lapse-rate effect from other factors. One aspect considered is the pronounced south-north gradient in projected European summer warming, which has an opposite latitudinal direction in comparison to annual-mean large-scale conditions. The basic idea of the surrogate approach is to apply a large-scale warming to the lateral boundary conditions of a present-day RCM simulation, while maintaining relative humidity (and thus implicitly increasing the specific moisture content). Two runs of the regional climate model COSMO-CLM with a grid spacing of approximately 50 km (EURO-CORDEX EUR-44 setup) are used as references: a regular control (1971-2000, CTRL) and scenario (2070-2099, SCEN) experiment driven by the global climate model MPI-ESM-LR and assuming the RCP8.5 greenhouse gas emission scenario. In a first experiment the warming (as estimated from SCEN-CTRL) is added to the CTRL simulation as a vertically and horizontally homogeneous warming and in a second case assumed to be a function of height, thereby accounting for lapse rate changes. Comparing these two cases allows to quantify the effect of a large-scale lapse rate change and to isolate the corresponding physical mechanisms.
Results show that an increase in lapse-rate leads to a stronger near-surface warming in the southern part of Europe (in comparison with the vertically uniform warming), and thereby an increased south-north temperature contrast. We find that this difference is significant and relates to reduced convective cloud cover and precipitation due to higher atmospheric stability and is potentially amplified by soil moisture-temperature feedbacks. We conclude that the strong gradient in south-north temperature change seen in most climate change projections over Europe is at least partly caused by large-scale lapse-rate changes.