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Improved dynamics due to introducing a nudging approach in the Community Earth System Model (CESM) and thermodynamic origin of the remaining errors

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The occurrence of extreme events such as droughts and heatwaves is favoured under certain atmospheric conditions. However, other components such as the ocean state and the land surface also play an important role for these events. These climate drivers interact with each other in complex ways and they may all contribute to weather extremes. In this study, we aim to detect the components significantly contributing to biases in the simulation of mean climate and extremes.

To separate dynamical from thermodynamical effects, we perform simulations with the Community Earth System Model (CESM) that include nudging of horizontal winds and compare them to simulations with a freely evolving atmosphere. Prescribing the observed large-scale circulation improves not only the modeled weather patterns but also many related fields such as precipitation and near-surface temperature. However, we find that a large part of the biases present in the free atmosphere configuration remains after nudging. This suggests that the origin of the biases lies in thermodynamical processes, including land-atmosphere coupling and atmospheric parameterizations. Similar results are obtained for climate extremes, with even lower improvements introduced by nudging: correcting the dynamics in the model does not significantly reduce the biases. Our results highlight that improving thermodynamical processes in models will be critical to reduce biases.