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The role of Hadley circulation and lapse-rate changes for the future European summer climate

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By the end of the current century, climate projections for southern Europe exhibit an enhanced near-surface summer warming in response to greenhouse gas emissions, which is known as the Mediterranean amplification. This amplified warming signal has been suggested to be related to various changing processes in the climate system, such as the poleward expansion of the Hadley cell or changes in the tropospheric lapse rate.
In this work, regional climate model (RCM) simulations driven by three different global climate models (GCMs) are performed, representing the RCP8.5 emission scenario. For every GCM, the climate change signal over Europe is separated into multiple contributions, each representing different changing processes in the climate system. The separation is achieved by modifying the lateral boundary conditions of the RCM and is related to the pseudo–global warming method. The separated processes range from thermodynamic changes to circulation changes.
We find that a poleward expansion of the Hadley cell is of minor importance for the Mediterranean amplification. During summer, the simulated Hadley circulation is weak, and projections show no distinct expansion in the European sector.
The north–south contrast in lapse-rate changes is suggested as the most important factor causing the Mediterranean amplification. Lapse-rate changes occur due to the temperature dependency of the moist-adiabatic lapse rate. While lapse-rate changes are projected throughout Europe during summer, they are weaker over the Mediterranean than over northern Europe, resulting in a strong near-surface summer warming over the Mediterranean. The spatially different lapse-rate changes can be understood as a thermodynamic response to lower-tropospheric humidity contrasts. In relatively moist northern European areas, strong lapse-rate changes occur, since moist-adiabatic vertical motions are frequent. In dry areas, like the Mediterranean, lapse-rate changes are weak since moist-adiabatic vertical motions are rare.
Thus, the projected enhanced summer warming in southern Europe is found to be linked to thermodynamic processes that are thought to be relatively reliable in climate projections, rather than to circulation changes.