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Idealized studies of convective summer precipitation in a cloud-resolving model

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Climate change is expected to moisten the atmosphere and to intensify the hydrological cycle. In the global mean, precipitation is projected to increase, but for Europe climate models suggest that mean summer precipitation will decrease. However, despite this decrease in mean, heavy precipitation events are projected to occur more frequently. The credibility of these projections, with decreases in mean amounts but increases in peak intensity, is somewhat limited, as convection is parameterized in current climate models due to its small-scale nature. Differences between climate models are especially large in summer, when synoptic-scale forcing is weak and the chosen model formulation has a great influence.

Here we investigate the sensitivity of convection to ambient temperature and humidity profiles in a cloud-resolving model (CRM), using a spatial resolution of 500 m - 2 km. The modeling strategy includes an idealized set-up with explicit convection and a full set of parameterizations. The variables are relaxed towards the prescribed profiles and soil conditions, but the relaxation is weak in the lower troposphere and upper soil, such as to allow the development of a diurnal boundary layer. The model is run for 30 days, after which the diurnal cycle approximately repeats itself. Analysis is conducted for the last 15 days of the simulations. A systematic set of experiments with different stratification and humidity profiles is performed.

We confirm that the temperature stratification of the environment has a dominant influence on the amount of precipitation by modifying the stability of the atmosphere and thereby the depth and intensity of convection. A more unstable stratification leads to deeper convective clouds and increased amounts of precipitation. In a more stable atmosphere convection remains shallow and precipitation amounts are small. The moisture profile influences the timing and duration of the precipitation period. Simulations with a drier atmosphere show larger values of convective inhibition (CIN) in the morning. In comparison to the standard simulation, the initiation of clouds and convection is delayed but occurs more sudden and intense than in the moister simulations, despite a reduction of mean precipitation amounts. We discuss this result in relation to the climate change scenarios mentioned above.