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Effect of soil moisture on diurnal convection and precipitation in Large-Eddy Simulations

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Soil moisture and convective precipitation are generally thought to be strongly coupled, although limitations in the modeling set-up of past studies due to coarse resolutions, and thus poorly resolved convective processes, have prevented a trustful determination of the strength and sign of this coupling. In this work the soil moisture-precipitation feedback is investigated by means of high-resolution simulations where convection is explicitly resolved. To that aim we use the LES (Large Eddy Simulation) version of the ICON model with a grid spacing of 250 m, coupled to the TERRA-ML soil model. We use homogeneous initial soil moisture conditions and focus on the precipitation response to increase/decrease of the initial soil moisture for various atmospheric profiles. The experimental framework proposed by Findell and Eltahir (2003) is revisited by using the same atmospheric soundings as initial condition but allowing a full interaction of the atmosphere with the land-surface over a complete diurnal cycle.

In agreement with Findell and Eltahir (2003) the triggering of convection can be favoured over dry soils or over wet soils depending on the initial atmospheric sounding. However, total accumulated precipitation is found to always decrease over dry soils regardless of the employed sounding, thus highlighting a positive soil moisture-precipitation feedback (more rain over wetter soils) for the considered cases. To understand these differences and to infer under which conditions a negative feedback may occur, the total accumulated precipitation is split into its magnitude and duration component. While the latter can exhibit a dry soil advantage, the precipitation magnitude strongly correlates with the surface latent heat flux and thus always exhibits a wet soil advantage. The dependency is so strong that changes in duration cannot offset it. This simple argument shows that, in our idealised setup, a negative feedback is unlikely to be observed. The effects of other factors on the soil moisture-precipitation coupling, namely cloud radiative effects, large-scale forcing, winds, and plants are investigated by conducting further sensitivity experiments. All the experiments support a positive soil moisture-precipitation feedback.

References:

-Findell, K. L., and E. A. Eltahir, 2003: Atmospheric controls on soil moisture-boundary layer interactions. part I: Framework development. Journal of Hydrometeorology, 4 (3), 552–569.