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The importance of spatial resolution and convective parameterisation in modelling soil moisture – precipitation feedbacks

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Soil moisture influences low-level temperature and humidity, which can strongly affect convective development. The location of convection in turn alters the soil moisture anomalies present on the following day, providing a feedback mechanism. Satellite observations show that in the tropics afternoon rainfall falls preferentially where the ground is drier than its surroundings. A large number of global weather and climate models, on the other hand, show a positive soil moisture – rainfall feedback, inconsistent with observations. This systematic bias will tend to exaggerate drought impacts in global atmospheric models, and points to missing fundamental processes in the models related to the coupling between the surface and convection. While the source of this error is still unclear, it has been hypothesized that the triggering of parameterisations of convection is excessively sensitive to low-level moisture, leading to convection initiating preferentially over wet soils.

Here we quantify the soil-moisture – precipitation feedback sign using the same method as in Taylor et al. (Nature, 2012), which is now part of the ESMValTool model evaluation toolbox. We analyse multi-year global simulations using the Met Office Unified Model (MetUM) with different resolutions and representations of convection. Three simulations are run at $\sim$15 km grid-spacing with different representations of convection: 1. the standard operational MetUM parameterisation scheme, 2. 'convection permitting', where the parameterisations of shallow and deep convection are turned off, and 3. only the parameterisation of shallow convection is turned on. The use of the same resolution and setup, except for the representation of convection, allows us to exclude any effects from changing resolution. Additional simulations at 30, 50 and 150 km grid-spacings using the standard MetUM parameterisation of convection scheme are then used to explore the impact of resolution.

All simulations show daytime precipitation occurring preferentially over dry soils in most regions, particularly in semi-arid locations. This is consistent with observations, but inconsistent with past analyses of climate models. At the coarsest resolution the results are sensitive to the time of day used for the analysis, and this may explain some of this discrepancy. Surface flux composites show that at high resolutions, both with and without the parameterisation, rainfall occurs preferentially over surface flux boundaries, rather than being a clear dry-soil advantage. This is consistent with surface-flux heterogeneities driving convergence over the boundaries, as seen in observations, and suggests that the parameterisation is getting the right answer for the right reasons. A binary wet-soil/dry-soil advantage may therefore not always be appropriate to evaluate models. At coarser resolutions there is a clearer dry advantage, which could be either due to differences in the coupling at coarser scales, or model bias.