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Aerosol effects on shallow cumulus cloud fields in idealised and realistic simulations

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Shallow cumulus clouds interact with their environment in myriad significant ways, and yet their behaviour is still poorly understood, and is responsible for much uncertainty in climate models. Improving our understanding of these clouds is therefore an important part of improving our understanding of the climate system as a whole.

Modelling studies of shallow convection have traditionally made use of highly idealised simulations using large-eddy models, which allow for high resolution, detailed simulations. However, this idealised nature, with periodic boundaries and constant forcing, and the quasi-equilibrium cloud fields produced, means that they do not capture the effect of transient forcing and conditions found in the real atmosphere, which contains shallow cumulus cloud fields unlikely to be in equilibrium.

Simulations with more realistic nested domains and forcings have previously been shown to have significant persistent responses differently to aerosol perturbations, in contrast to many large eddy simulations in which perturbed runs tend to reach a similar quasi-equilibrium.

Here, we further this investigation by using a single model to present a comparison of familiar idealised simulations of trade wind cumuli in periodic domains, and simulations with a nested domain, whose boundary conditions are provided by a global driving model, able to simulate transient synoptic conditions.

The simulations are carried out using the Met Office Unified Model (UM), and are based on a case study from the Rain In Cumulus over the Ocean (RICO) field campaign. Large domains of 500km are chosen in order to capture large scale cloud field behaviour. A double-moment interactive microphysics scheme is used, along with prescribed aerosol profiles based on RICO observations, which are then perturbed.

We find that the choice between realistic nested domains with transient forcing and idealised periodic domains with constant forcing does indeed affect the nature of the response to aerosol perturbations, with the realistic simulations displaying much larger persistent changes in domain mean fields such as liquid water path and precipitation rate.

