Evaluating Memory Properties in Convection Schemes Using Idealised Tests

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Two structural assumptions are frequently employed in convective parameterisation: the diagnostic and quasi-equilibrium assumptions. The former assumes an instantaneous relationship between the large-scale environment (“macrostate”) and subgrid-scale convective activity, while the latter postulates that convective processes are almost in equilibrium with slowly evolving large-scale forcing at all times. Both assumptions do not take into account the role of convective memory (“microstate” memory), which is defined as the dependence of convection on its own history. Here, we present the memory behaviour of three convection schemes by comparing their responses in two idealised RCE experiments in single-column models (SCMs) to those of a cloud-resolving model (CRM). Three main findings from these tests will be discussed. First, when the large-scale environment is held constant (“FixMacro”), precipitation remains invariant in time with the Zhang-McFarlane scheme, confirming that the scheme does not parameterise convective memory and is fully diagnostic. The org scheme (Mapes & Neale, 2011) displays similar behaviour to the CRM in that precipitation increases in the first moments after FixMacro starts, with larger entrainment rates associated with slower growth. However, its logarithmic growth shape differs from that of the CRM, which displays exponential growth, and can be explained using the scheme’s governing equations. Second, when the prognostic convective memory variable is set to zero at one time step (essentially wiping out microstate memory), the org scheme displays remarkably similar behaviour to the CRM, with precipitation dropping to zero and then recovering to its RCE value over a recovery time scale $t_{mem}$. In comparison, precipitation in the LMDZ cold pool scheme (Grandpeix & Lafore, 2010) responds in the opposite direction: it grows and then falls back to its RCE value. Finally, the mean and temporal variance of the org variable were found to correlate strongly with memory strength ($t_{mem}$), indicating that org has captured important aspects of convective memory. Overall, our results indicate that the org and LMDZ cold pool schemes partially, but do not fully capture CRM memory behaviour and are limited by their structural assumptions. They also demonstrate the usefulness of our simple idealised experiments to probe the memory behaviour of convection schemes.