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Developing emulators of a general circulation model for applications in Earth system modelling

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To study climate change on multi-millennial timescales, efficient models with simplified and parameterized processes are required. This is particularly important if observations are to be used effectively constrain models, an endeavour which demands large numbers of simulations. Unfortunately, the reduction in explicitly modelled processes can lead to underestimation of responses in the system that are essential to the understanding of palaeoclimate. To address this, we intend to replace a simple component of an efficient model with a statistical model (an emulator) of a more comprehensive one. Efficient construction of such an emulator is achieved by exploiting the relationship among different levels of the climate model hierarchy.

Using a multi-level emulation technique, outputs from an atmospheric general circulation model (GCM), called PLASIM, are efficiently emulated by utilising the extra information gained from the computationally cheap atmosphere of an efficient model called GENIE-1. Even though the two atmospheric models chosen have large structural differences, useful links between them are identified and Gaussian process emulators of PLASIM 2-D surface air temperature and precipitation fields are successfully constructed.

The result shows that the multi-level emulators of PLASIM's output fields can be built using only one third the amount of expensive data required by the normal single-level technique. The constructed emulators are shown to capture 95.4% and 80.3% of the variance in surface air temperature and precipitation, respectively, across a validation ensemble.

GCM emulators constructed using the proposed method can potentially replace the current simple component of the efficient model, resulting in a higher fidelity version of the model without a significant increase in computational cost.