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The Use of Scale-Dependent Precision to Increase Forecast Accuracy in Earth System Modelling

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At the current pace of development, it may be decades before the ‘exa-scale’ computers needed to resolve individual convective clouds in weather and climate models become available to forecasters, and such machines will incur very high power demands. But the resolution could be improved today by switching to more efficient, ‘inexact’ hardware with which variables can be represented in ‘reduced precision’. Currently, all numbers in our models are represented as double-precision floating points – each requiring 64 bits of memory – to minimise rounding errors, regardless of spatial scale. Yet observational and modelling constraints mean that values of atmospheric variables are inevitably known less precisely on smaller scales, suggesting that this may be a waste of computer resources. More accurate forecasts might therefore be obtained by taking a scale-selective approach whereby the precision of variables is gradually decreased at smaller spatial scales to optimise the overall efficiency of the model.

To study the effect of reducing precision to different levels on multiple spatial scales, we here introduce a new model atmosphere developed by extending the Lorenz ‘96 idealised system to encompass three tiers of variables – which represent large-, medium- and small-scale features – for the first time. In this chaotic but computationally tractable system, the ‘true’ state can be defined by explicitly resolving all three tiers. The abilities of low resolution (single-tier) double-precision models and similar-cost high resolution (two-tier) models in mixed-precision to produce accurate forecasts of this ‘truth’ are compared. The high resolution models outperform the low resolution ones even when small-scale variables are resolved in half-precision (16 bits). This suggests that using scale-dependent levels of precision in more complicated real-world Earth System models could allow forecasts to be made at higher resolution and with improved accuracy. If adopted, this new paradigm would represent a revolution in numerical modelling that could be of great benefit to the world.