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Inexact hardware in geophysical modelling and the use of rounding errors to represent sub-grid-scale variability

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The use of inexact hardware is promising large savings in power consumption and an increase in computational performance. This would allow an increase in resolution in weather and climate models and might be a short-cut to global cloud-resolving modelling. However, simulations with inexact hardware show numerical errors, such as rounding errors or bit flips, that can be interpreted as a forcing added to the differential equations that is almost uncorrelated in space and time.

We investigate how rounding errors of inexact hardware will influence numerical simulations of geophysical relevance in the hierarchy of models (from Lorenz '95 all the way up to OpenIFS) and provide estimates of possible savings for different approaches to inexact hardware that proof the huge potential of inexact hardware. We present results of studies on the impact of hardware errors on model dynamics at different spatial scales and the interactions between the rounding error forcing and stochastic forcings of stochastic parametrisation schemes.

We find that a scale selective approach that introduces rounding errors into the computation of small scale dynamics has huge potential due to their high inherent uncertainty due to viscosity, sub-grid-scale variability and parametrisation schemes. We also find that rounding errors can be hidden inside the distribution of stochastic forcings of stochastic parametrisation schemes and that rounding errors can be used to generate forecast ensembles of similar spread and quality compared to ensembles based on stochastic parametrisation schemes, at least in idealised test cases. We conclude that rounding errors are not necessarily degrading the quality of model simulations. On the contrary, rounding errors can be beneficial to the representation of sub-grid-scale variability in geophysical modelling.