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Inexact hardware and the trade between precision and performance in earth system modelling

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We study the use of inexact hardware in numerical weather and climate models. Inexact hardware is promising a reduction of computational cost and power consumption of supercomputers and could be a shortcut to higher resolution forecasts with higher forecast accuracy and exa-scale supercomputing. However, simulations with inexact hardware show numerical errors, such as rounding errors or bit flips.
In cooperations with groups in computing science, we studied different approaches to inexact hardware that include *the use of stochastic processors*: the applied voltage in computing hardware is reduced to save power, but bit flips are possible, *the use of pruned hardware*: parts of the floating-point unit that are either hardly used or do not influence significant bits are removed, *the use of Field Programmable Gate Arrays (FPGAs)*: An FPGA is a programmable hardware that allows flexible floating-point precision, *and the use of inexact memory* within simulations of numerical models for weather and climate predictions. Results show that numerical precision can be reduced significantly within simulations of the three dimensional atmosphere with no significant increase in model errors. If computational cost is reduced due to the use of inexact hardware, the possible increase in resolution will allow a stronger reduction of model errors compared to the increase of model errors due to reduced precision.
We treat different parts of atmospheric models with customized computational accuracy to reflect inherent uncertainties. Planetary scale waves are more predictable and less uncertain than meso-scale waves. For small-scale dynamics, diffusion, parametrisation schemes, and sub-grid-scale variability cause large inherent uncertainties. An approach of scale separation that calculates the dynamics of expensive small scales with low numerical precision and the dynamics of large scales with high precision has proved to be very efficient.