Optimum numerical calculation with mixed precision floating point number for a regional shallow-water model

*Yamaura Tsuyoshi[1], Hirofumi Tomita[1]

1. RIKEN Advanced Institute for Computational Science

We investigate the impact of numerical errors of floating point numbers (FPNs) to the equilibrium and instability condition experiments, using a regional shallow-water model with mixed precision FPN by a reduced precision emulator. To express the numerical errors quantitatively, we define the reproducibility index that is the mean ratio of root-mean-square-error to standard deviation of prognostic variables. The results of the ideal experiments are listed as follows: (1) Higher spatial resolution requires larger size of significand bit width. (2) Preparing a reference value, which is made from horizontal mean of a variable before time integration, is effective in reducing loss of significand digits. (3) Reducing accuracy of FPN before making the reference value of geopotential may induce large loss of significand digits, while that of velocity is relatively small contribution to the loss. (4) A careful summation algorithm for a large number of grids can avoid loss of trailing digits that induces low accuracy of the reference value. (5) The time evolution of numerical errors can be expressed as an exponential function form. Therefore, reducing initial numerical errors is crucial for preserving high reproducibility with time evolution. Following the above results, we construct an optimum shallow-water model that uses single precision FPN to dynamics kernel. The optimum model can obtain the results with slight numerical errors, compared with the shallow-water model fully using double precision FPN. In contrast, execution time of the optimum model is comparable to that of the shallow-water model fully using single precision FPN. The results of this work suggest the base of dynamics kernel with high cost-performance, which can be also applied for the dynamics kernel in a numerical weather prediction model on a high-performance computer.

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