Implementation of two dimensional decomposition for JMA non-hydrostatic model

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1 Introduction

These days massively parallel computers are becoming more popular. The JMA non-hydrostatic model (JMANHM) was parallelized for the distributed memory super computer by using MPI libraries in the way that the entire domain is decomposed in a single direction and each subdomain is assigned to an MPI process. However, the parallel efficiency of the model is not very high with a large number of computational nodes due to the load imbalance among the nodes. Therefore we tried to increase computational efficiency by implementing two dimensional decomposition.

2 Domain decomposition and computational efficiency

We are planning to replace the current operational meso-scale model with JMANHM in 2004. The number of grid points of the operational JMANHM will be 361 × 289 × 40. Therefore first the acceleration rate of this number of grid points was investigated. Figure 1 shows the acceleration rate of JMANHM according to the investigation which was carried out on HITACHI SR8000/E1. This figure shows that the parallel computational ratio does not effectively increase with more than 24 nodes of the computer system.

As is mentioned in section 1, the entire domain of JMANHM was divided only for the latitudinal direction (Fig. 2) in its original design for the parallel treatment, and each subdomain includes 'ghost points' for processes referring to status at the adjacent points. Since the number of the grid points in the north-south direction of each subdomain becomes small with increasing number of nodes, the load imbalance of this decomposition scheme tends to be large with more computational nodes. Thus the parallel efficiency decreases with increasing number of the subdomains, namely, the MPI processes. To improve the computational efficiency, we introduced two dimensional decomposition which is illustrated in Fig. 3. Suppose the grid points 361 × 289 × 40 are handled with 40 MPI processes, the excess of the maximum area size to the minimum is as large as 14 percent in the one dimensional case, while it can be reduced to 4 percent with two dimensional optimal decomposition.

The two dimensional decomposition does not always have advantage over the one dimensional decomposition in computational efficiency, because

- the vector length becomes shorter by the division in x-direction, and
- the communication overhead becomes twice to communicate with all four neighboring processes.

The efficiency depends mainly on the architecture of a particular machine, the number of the model grids, and the number of MPI processes used.

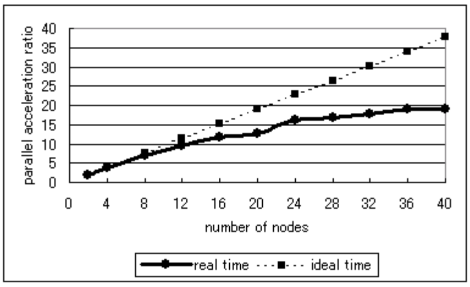

Fig. 1 Acceleration rate.

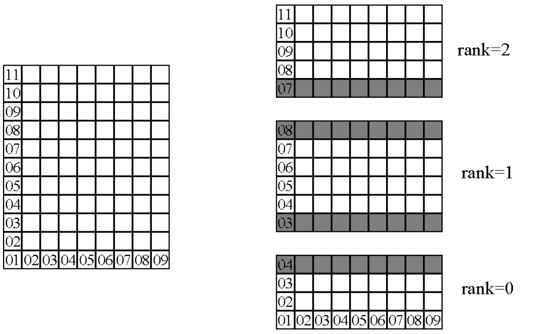

Fig. 2 One dimensional decomposition (case of 3 MPI processes).

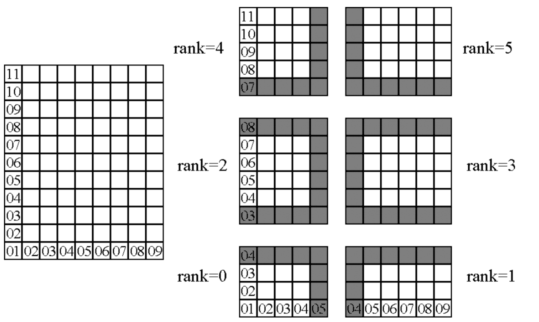

Fig. 3 Two dimensional decomposition (case of 6 MPI processes).

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3 Validation and comparison of computational cost

Tests for validation and comparison of computational cost were carried out. The tests were conducted with 40 nodes of HITACHI SR8000/E1 which are used for operational NWP by JMA. Each node is assigned one MPI process. 39 nodes are used for computation, and one for data output to execute computation and output simultaneously. Table 1 shows the specifications of the tests. Figures 4 and 5 are the results of six-hour integration of the one dimensional and two dimensional decomposition, respectively. The three-hour accumulated rainfall amount, sea level pressure, and surface wind are shown in these figures. The result of the two dimensional decomposition of 3 × 13 is almost identical to that of one dimensional decomposition of 1 × 39 except for trivial differences which reflect the changes of the computational procedure. The computational cost of the two runs are shown in Table 2. The increase of the computational time for-preprocessing becomes less important if forecast time is longer. We got the improvement of 1.7 percent of computational time with the two dimensional decomposition in time integration.

Table 1 Specifications of tests.

number of grid points	361 × 289 × 40
horizontal resolution	10 km
vertical resolution	40-1180 m
time step	40 sec
initial time	06UTC 20 December 2003
forecast time	6 hours
computer	HITACHI SR8000/E1
number of nodes	40 nodes
peak performance	384 GFLOPS
time integration	split-explicit
advection scheme	horizontally 4th order centered flux form
prognostic variables	$U, V, W, p, \theta, qv, qc, qr, qi, qs, qg$

4 Summary

Two dimensional decomposition is successfully implemented for JMANHM. The procedure improved the computational efficiency even with the current supercomputer at JMA. The new function is expected to have larger impact especially on huge scalar architecture machines where the computational efficiency does not depend on the vector length.

Table 2 Computational elapsed time (sec) of 6 hours forecast.

	1 × 39	3 × 13
pre-processing	13.95	20.78
time integration	508.96	500.48
I/O	34.18	32.16
total time	557.09	553.42

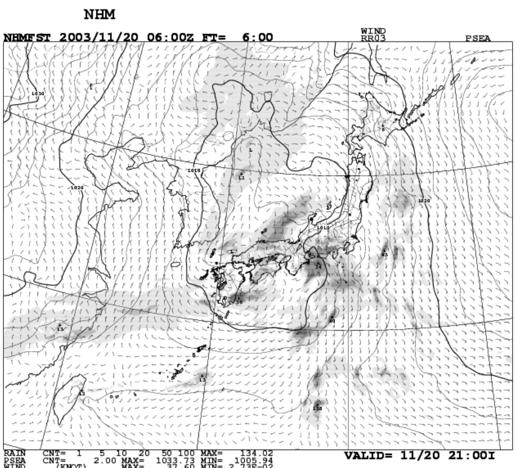

Fig. 4 Result of 1 × 39.

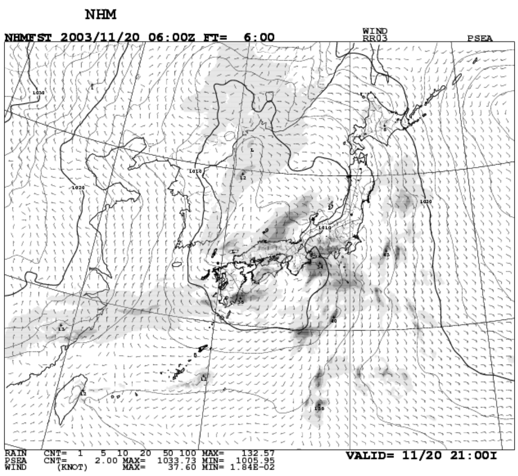

Fig. 5 Result of 3 × 13.