AGCM parallel realization on cluster.

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One of the purposes of the work is to analyze components of AGCM algorithm and their parallel performance depending on computing program efficiency, to find bottlenecks that hinder the parallel scalability of the code, and use better algorithms and more efficient parallel implementation strategies to maximize the performance of the AGCM code on scalable parallel systems.

Computing Centre (CC) AGCM uses uniform 72 on longitude and 46 on a latitude horizontal grid for single processor computer. Program was modified for high performance cluster. An analysis is presented of the primary factors influencing the performance of a parallel implementation of AGCM on distributed-memory, cluster computer system. Several modifications to the original parallel AGCM code aimed at improving its numerical efficiency, load-balance code performance are discussed. The climate model includes the atmospheric block realized on the basis of AGCM with physical processes parameterization. Versions of model with fine spatial grid and the ocean general circulation model are developed. Interaction between blocks is carried out in an interactive mode. The model has rather coarse spatial grid, however relatively low computing expenses allows to investigate mechanisms and ways of parallelization for research their efficiency and definition of bottlenecks.

Domain decomposition in horizontal directions is used in parallel realization of the model. This choice is based on the fact that vertical processes strongly connect grid points that make parallelization by less effective in a vertical direction, and that the number of grid points in a vertical direction is usually small. Each grid cell is rectangular area which contains all points of a grid in a vertical direction.

There are two major components of the code: AGCM Dynamics, which computes the evolution of the fluid flow governed by the primitive equations by means of finite-differences, and AGCM Physics, which computes the effect of processes not resolved by the model's grid (such as convection on cloud scales) on processes that are resolved by the grid. The results obtained by AGCM Physics are supplied to AGCM Dynamics as forcing for the flow calculations. The AGCM code uses a three dimensional staggered grid for velocity and thermodynamic variables (potential temperature, pressure, specific humidity, ozone, etc.).
The AGCM Dynamics itself consists of two main components: a spectral filtering part and the actual finite difference calculations. The filtering operation is needed at each time step in regions close to the poles to ensure the effective grid size there satisfies the stability requirement for explicit time difference schemes when a fixed time step is used throughout the entire spherical finite-difference grid.

In this case there are basically two types of interprocessor data exchanges. Data exchanges are necessary between logically next processors (units) at calculations of final differences; the removed data exchanges are necessary to carry out operations of spectral filtering, in particular. It is found that implementation of a load-balanced Fourier algorithm results in a reduction in overall execution time of approximately 40% compared to the original algorithm.

The basic part of computing expenses of AGCM is connected with the Dynamics component and the Physics component, with the excluded procedures of input-output. These procedures are carried out only once whereas the main components are calculated repeatedly on time and dominate on expenses of performance time. Comparing the two modules in the main body, we can see the Dynamics part is dominant in cost especially on large numbers of nodes. Furthermore, timing analysis on the Dynamics part indicates that the spectral filtering is a very costly component with poor scalability to large number of nodes

The physical block of AGCM carries out local calculations without interprocessor exchanges. Distribution of computing loading in the physical block changes in time and space at the account of model and non-uniformity of loading of processors achieves 50 %. The amount of calculations in each grid point is defined by several factors: time of day, distribution of clouds, presence cumulus convection. Difficulty of maintenance of uniformity of loading of the physical block is unpredictability of distribution of clouds and distributions cumulus convection. The estimation of each processor loading is required before realization of the effective loading balancing. Preliminary results of the application of a load-balancing scheme for the Physics part of the AGCM code suggest additional reductions in execution time of 15-20% can be achieved.

The analysis of some factors influencing performance of AGCM parallel realization on the cluster is submitted. Some updating of an initial parallel AGCM code, directed on improvement of its computing efficiency, balance of processors loading are discussed. It is revealed, that performance of the balanced loading of algorithm of spectral smoothing provides reduction of performance time approximately on 40 %, in comparison with initial algorithm. Test calculations on high-efficiency cluster are carried out.

Realization of the parallel program for various ways of splitting of global area on processors in climatic model is carried out. Updating of the time integration numerical scheme for an opportunity of realization of parallel calculations of dynamics and physics blocks with an estimation of computation efficiency is carried out. The analysis shows, that results of calculations under the modified scheme yields satisfactory results and its application is possible. In the scalar program physics block run time takes 38%, and dynamics block run time - 62%. It means that parallel program acceleration in one and a half time can be achieved. Offered procedure is used together with parallel computations of dynamics and physics blocks on the basis of global area decomposition. It allows to optimize loading of processors and to increase program efficiency. Results of application of loading balance of the physics block of AGCM enable additional reduction of running time on 15-20 %. Other opportunity of method application is a complication of the physics block without increasing of total computational time.

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References

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