Large Atmospheric Computation on the Earth Simulator : A report on the LACES project

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We have been preparing LACES, Large Atmospheric Computation on the Earth Simulator, in which the life cycle of hurricane Earl (September 1998) is simulated with the 1-km mesh version of the Canadian MC2 Community Model. MC2 was installed on the Earth Simulator in November 2003. Computational optimization and production will start in April 2004. We are also planning to perform a twin experiment with the T1279L96 (horizontally 10-km mesh and vertically 96 levels) version of AFES (AGCM for the Earth Simulator). By comparing the above two experiments, we expect to gain a better understanding of the dynamics of extratropical transition and redevelopment of hurricanes.

Keywords: The Earth Simulator, hurricane Earl, ultra-high resolution simulations, life cycle of hurricane, extratropical transition and redevelopment of hurricanes

1. Introduction

A long-term collaborative effort between scientists from the Earth Simulator Center (ESC), McGill University and Recherche en Prévision Numérique (RPN) is now focusing on simulating the full life cycle of hurricane Earl (September 1998) with the Canadian MC2 Community Model. In this regional simulation, cumulus convection is explicitly resolved in 1-km mesh resolution. We named this experiment, LACES, Large Atmospheric Computation on the Earth Simulator.

We are also planning to perform a twin experiment with a 10-km mesh global atmospheric model, AFES, in which cumulus convection is parameterized. It is known that AFES can simulate tropical hurricanes. By comparing the AFES result with the one from MC2, it is expected to get a better understanding of the effects of cumulus convection on life cycle of hurricanes.

2. LACES with Canadian MC2 Community Model

The goal of LACES is to produce a 1 km horizontal resolution forecast over a very large domain (Fig. 1) which covers the tropical phase and extratropical redevelopment of hurricane Earl. In fact, we wish to produce 8–9 days of simulation on a fine-resolution domain of size $11000 \times 8640 \times 67$. This reference simulation will be used to validate various lower resolution simulations, including the twin experiment with AFES described in the next section, and to improve our understanding of the extratropical transition of hurricanes. Of course this represents a major computational effort that can only be performed – at least for the moment – on the Earth Simulator, using around 80% of the total resources of the system for up to 10 full days of computation.

This project also poses a real challenge for the MC2 modelling system itself considering that the computing work is distributed on 3960 vector processors (495 out of 640 nodes) [1]. Inter-processor communications are potentially becoming an issue with such a large number of processors [2]. It also represents a real test for the numerics of the elliptic solver considering that order 10 Giga-equations are solved at once by an iterative 3D pressure solver based on FGMRES. I/O is also a very important issue that must be treated carefully. Even the simple display of meteorological fields on horizontal planes is far beyond the limit of current display technology.

MC2 was installed on the ES in November 2003. Scalability tests were performed and so far we were able to

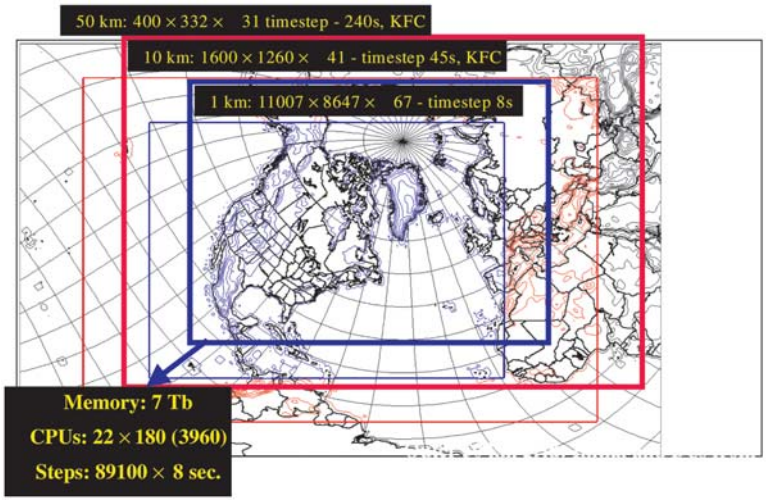

Fig. 1 Computational domain of LACES.

run the model on 140 nodes. The next phase is scheduled to start in April 2004. More scalability tests will be performed on up to 495 nodes. Project LACES should thereafter move to its production phase which is expected to last 2–3 months.

3. AFES Experiment

AFES, AGCM For the Earth Simulator, was adopted from the Japanese CCSR/NIES AGCM [3]. It was, however, totally rewritten with FORTRAN90, MPI and microtasking and optimized for the architecture of the Earth Simulator while the original code was written in FORTRAN77 and was not parallelized. AFES achieved 26.58 Tflops with the full configuration of the Earth Simulator (640 nodes or 5120 CPUs) and won Gordon Bell Award for the Peak Performance at Super Computing 2002 [4].

It has been known that AFES can simulate a lifecycle of typhoons. Fig. 2 shows twin typhoons that appear in an AFES simulation with the so-called T1279L96 (horizontally 10-km mesh and 96 vertical levels) resolution. The typhoon on the right moves northward and experiences extratropical transition [5]. Note that AFES uses parameterized cumulus convection and cannot resolve convection explicitly because of the resolution. By comparing the AFES simulation of hurricane Earl with the MC2 simulation, it is expected to get a better understanding on the role of cumulus convection on extratropical transition and redevelopment.

4. Summary

We have been preparing LACES, Large Atmospheric Computations on the Earth Simulator, in which a 1-km mesh MC2 simulation of a life cycle of hurricane Earl will be conducted. We are also planning to perform a twin experiment with AFES, a global atmospheric general circulation model. We are expecting that these simulations will reveal dynamics of extratropical transition and redevelopment of hurricanes.

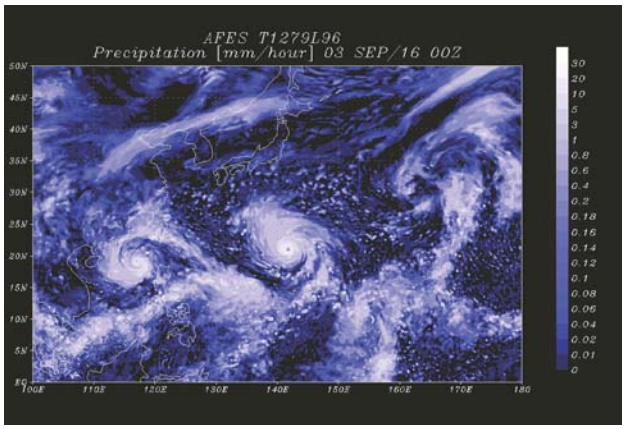

Fig. 2 Twin typhoons simulated in a numerical experiment with AFES.

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