Improvements to Parallel Algorithms for Climate Modeling

Proposal to the ESD-CHAMMP Program for Notice 94-07

J.B. Drake
Research Associate, Mathematical Sciences Section
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-8083

D.L. Williamson
Senior Scientist and Head, Climate Modeling Section
National Center for Atmospheric Research
Boulder, Colorado

I. Foster
Computer Scientist, Math. and Computer Sciences Division
Argonne National Laboratory
Chicago, Illinois

Abstract

We will perform research for the CHAMMP program in the use of parallel supercomputers to increase the throughput of climate simulations and to more accurately represent key climate processes. We will also support CHAMMP by investigating numerical methods for atmospheric flow modeling with the potential for longer time steps combined with accurate spatial resolution and a fine grain parallelism. The research proposed seeks to establish the methods required for a state-of-the-science atmospheric model on parallel computing platforms that functions as one component of a coupled advanced climate model. The NCAR Community Climate Model, CCM2, the semi-Lagrangian version of the CCM2 and their parallel versions are the starting point for the proposed research. As a continuation of two successful FY92-FY94 CHAMMP grants, this project maintains the focus of providing the research necessary to move the CCM2 beyond its current limitations.

The following tasks are included:

- improvement of the semi-Lagrangian version of CCM2 to better represent climate dynamics,
- development of more efficient parallel semi-Lagrangian transport algorithms,
- discretization of the horizontal pressure gradient and the σ coordinate system,
- the Cartesian method for solving the shallow water equations on the sphere,
- consideration of the reduced grid for spectral transform and semi-Lagrangian algorithms,
- quasi-homogeneous and irregular grid methods,
- development of sophisticated load balancing strategies in conjunction with reduced grids and alternative grid decompositions.

The development of the grid point based semi-Lagrangian model will be at a slower pace. Items that we have chosen to omit from our original proposals include,

- development of flexible dynamics and physics grid decompositions for efficient parallel implementations,
- fast solution of the spherical Helmholtz problem arising from semi-implicit treatment of the governing equations.
- parallel communication algorithms for mesh connected multiprocessors,

These research tasks will be addressed in a collaboration of researchers from the National Center for Atmospheric Research, Oak Ridge National Laboratory and Argonne National Laboratory.

Funding Request

	FY95	**FY96**	**FY97**
Budget Request(x $1000)	600	622	647

Expected Progress

As a three site collaboration we hope to continue to work as on previous projects with quarterly working meetings and a lively e-mail correspondence. The tasks proposed require coordination and a clear understanding of responsibilities among the team. In outline, the basic formulation of the models will be determined by Williamson and Hack with particular numerical methods chosen in consultation with ORNL and ANL. NCAR will also direct the studies necessary to establish new model formulation effects on the model climatology. Parallel SLT methods and the methods for the Helmholtz solvers will be the responsibility of ORNL while load balancing and general methods for grid decompositions will be a focus for ANL. Since these areas are intertwined we can further specify that Drake and Michalakes will consider the implications of SLT and mesh. Drake, Worley and Williamson will work on the particular form of the Helmholtz problem with ORNL considering the parallel and numerical algorithms.

The descriptions of projects proposed above have been organized by topic: 1) the development of new, improved atmospheric components for climate models and 2)the development of effective, flexible grid decompositions and parallel algorithms necessary for the parallel implementations of atmospheric climate models. In this section we outline the progression of proposed projects over the 3 year period.

Expected Progress 1995

- parallel semi-Lagrangian shallow water code developed and algorithmic studies completed,
- research version of fully semi-Lagrangian PCCM2 produced,

- spectral reduced grid model developed and climatology established,
- examination of the nature of the vertical errors in semi-lagrangian and Eulerian versions of CCM2.

Expected Progress 1996

- semi-implicit Helmholtz solver developed for semi-Lagrangian grid based models,
- parallel grid decompositions for SLT and reduced grid demonstrated in shallow water code,
- reduced grid version of PCCM2 produced,
- load balancing in context of reduced grids,
- consider various filters for surface geopotential,
- study grid point approximations for gradient operators in the semi-Lagrngian version of CCM2.

Expected Progress 1997

- results from study of σ coordinates and horizontal pressure gradients,
- begin conversion to non-spectral semi-Lagrangian climate model,
- parallel semi-implicit Helmholtz solver developed for semi-Lagrangian grid based models,
- parallel non-spectral semi-Lagrangian climate model produced that takes advantage of a reduced grid and proper load balancing.