CHAMMP Program Overview

M. C. MacCracken
Atmospheric and Geophysical Sciences Division
Lawrence Livermore National Laboratory
Livermore, CA 94550

The Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP) program is a relatively new component of the Global Change Research Program sponsored by the Environmental Sciences Division (ESD) of the U.S. Department of Energy (DOE). Dr. David Bader leads the program, assisted by Dr. Robert Malone and myself.

CHAMMP is an integral part of the ESD climate modeling program and its objectives are highly complementary to the modeling activities being conducted as part of DOE's Program for Climate Model Diagnosis and Intercomparison. CHAMMP is also closely linked to the U.S. Global Change Research Program, especially through its interactions with the major climate modeling centers of the other agencies. Because of its need for and focus on use of forefront supercomputers, CHAMMP is also a contributing program in the High Performance Computing and Communications Program, which is a new Presidential Initiative dedicated to the "grand challenge" computational problems. Just as the Atmospheric Radiation Measurement (ARM) program was formed in recognition of the inability of current general circulation models (GCMs) to satisfactorily represent cloud formation, convection, and radiative processes, the CHAMMP program was organized in response to the need to harness greater computational power in the pursuit of regionally resolved projections of climate change.

For a number of reasons, current GCMs simply are not adequate for making accurate projections of future climate. The types of problems for which models must be developed and tested include coupled ocean-atmosphere simulations with 50- to 100- km resolution and extending centuries in duration, simulations that represent the evolution of atmospheric composition from 1750 out to 2100, simulations of the evolution of global ecosystems and biogeochemical cycles, and studies of paleoclimatic changes. Table 1, taken from the CHAMMP Program Plan (DOE 1990), compares the current state of modeling capabilities with what is needed.

The goal of the CHAMMP Climate Modeling Program is to develop, verify, and apply a new generation of climate models within a coordinated framework that incorporates the best available scientific and numerical approaches to represent physical, biogeochemical, and ecological processes; that fully utilizes the hardware and software capabilities of new computer architectures; that probes the limits of climate predictability; and, finally, that can be used to address the challenging problem of understanding the greenhouse climate issue through the ability of the models to simulate time-dependent climatic changes over extended times and with regional resolution.

Implementing all of these improvements and extensions in a single model will require an increase in effective computational throughout of 10^4 to 10^6 or more. CHAMMP is aiming to achieve a factor of 10^2 by the mid-1990s and 10^4 by the end of the decade through a combination of the use of faster computers (e.g., massively parallel computers are projected to achieve a factor of 10^3 increase) and advances in the efficiency and accuracy of computational algorithms (a factor of 10 improvement is needed; use of a variable grid, for example, may provide similar accuracy to a fine, uniform grid, but at reduced computational cost, thereby increasing effective computational throughput).

The CHAMMP program is currently divided into two components. The scientific component, which I lead, will focus on a range of questions concerning what scientific capabilities must be included in the next generation of climate models in order to achieve accurate, regionally resolved projections of climatic change. Typical issues relate to the relationship of resolution to predictability, the inherent natural variability of the system, how best to represent processes on finer scales, and new techniques for solving the intercoupled set of equations governing the climate system. Members of the CHAMMP Science Team are being selected from universities, industry, and DOE and other agency laboratories based on competitive review of submitted proposals.

Table 1. Current versus needed capabilities of climate models.

Current State of Modeling Capability	Needed Modeling Capability	Required Gain in Computational Capability
1. Horizontal resolution of hundreds of kilometers that is unable to treat regional and watershed-size domains	1. Horizontal resolution of tens of kilometers that permits treatment of watershed-size domains	10^2 to 10^3
2. Inadequately verified and over-simplified treatments of important processes such as radiation, clouds, convection, and hydrology	2. Physically realistic and thoroughly tested treatments of all important processes, including clouds, surface processes, snow cover, sea ice, etc.	2 to 10
3. Restricted representation of the ocean, often including only the upper mixed layer of the oceans; empirically constrained coupling of the atmosphere-ocean domains	3. Fully coupled simulation of the atmosphere-ocean system, including treatment of the deep ocean and horizontal transport by ocean currents	
4. Separate, uncoupled, and limited treatment of atmospheric composition, chemical interactions, and aerosol effects	4. Interactive treatment of the roles and interactions of important species such as ozone and aerosols	
5. Very limited treatment of biosphere-climate interactions affecting albedo, hydrology, and other surface processes	5. Comprehensive treatment of the interactive role of the terrestrial and marine biosphere on the climate	about 2
6. Single-model simulations of tens of years with relatively coarse resolution	6. Multiple-model simulations of hundreds of years and the methodology to explore the resulting output for changes in climate variability, time-dependent climate evolution, predictability, and sensitivity to uncertain input parameters	10 to 10^2

The second component focuses to a greater extent on the computational implementation of climate models on massively parallel computers. This directed component of the program, led by Robert Malone, is being undertaken by staff members at DOE laboratories (Argonne National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Oak Ridge National Laboratory) and at the National Center for Atmospheric Research and the Geophysical Fluid Dynamics Laboratory through collaborative agreements. Issues to be addressed in these studies include the relative merits of various architectures, balancing the computational load among processors, etc.

The CHAMMP program is designed as a three-phase effort:

Phase 1 (Years 1 through 3):

During this period, the emphasis of the directed program is on transfer of existing ocean, atmosphere, and coupled GCMs to advanced and emerging new highly parallel platforms. The emphasis of the scientific component of the program is on exploring what range of processes, level of detail, etc., must be included in the next generation of climate models.

Phase 2 (Years 3 through 6):

During this phase, a prototype next-generation climate model will be assembled and tested from the emerging set of improved process modules. The objective is to achieve an increase in effective computational throughput of a factor of 100. The model will be used in initial studies to better understand factors affecting the degree of climate predictability that is potentially achievable.

Phase 3 (Years 7 through 10):

During this phase, the objective is to develop, verify, and initiate application of an advanced climate modeling system capable of an effective performance of 10 Teraflops.

Throughout this effort, the intent is to closely involve the scientific community and to make all models developed available for use (subject to computer resource constraints).

During FY91, the CHAMMP Program Plan was published (DOE 1990), about 13000 Cray-1 equivalent hours of computer time were awarded for scientific studies and model intercomparison, 89 science team proposals were

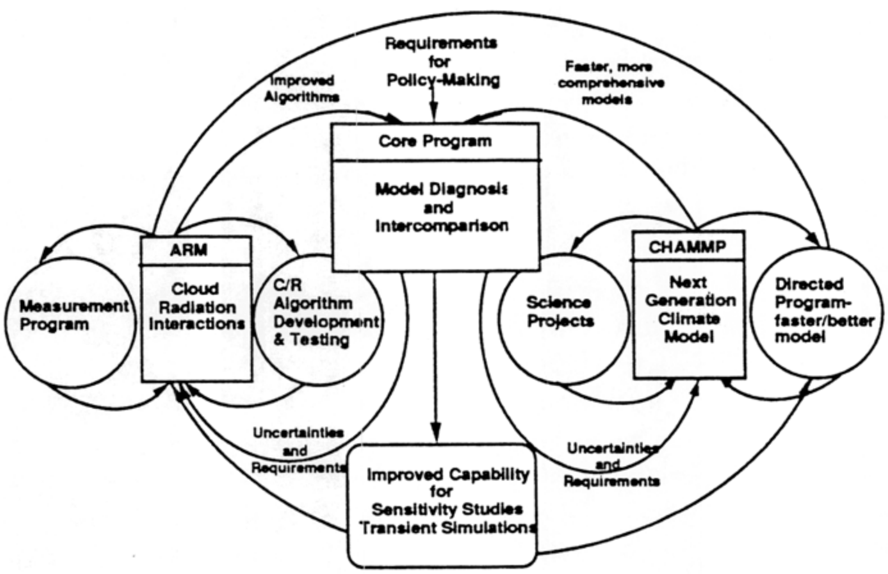

Figure 1. The DOE Core Modeling Program, ARM, and CHAMMP, together with modeling programs sponsored by other agencies compose a set of programs that, with coordination, can lead to significant improvements in the capability to project climatic change.

reviewed, and a series of early pilot projects was completed. These pilot projects included transfer of both atmosphere and ocean models to massively parallel architectures (e.g., the Semtner-Chervin OGCM ran on the CM-2 with equivalent speed to a YMP-8). For FY92, CHAMMP will distribute $10M, equally distributed to the outside-DOE Science Team members, the DOE Science Team members, the directed part of the program, for CRAY-class computer resources, and for massively parallel computer resources. CHAMMP will also be hosting and co-organizing workshops on various aspects of its research program.

Together, the ARM, CHAMMP, and Core Modeling Programs, working in coordination with the modeling programs of other agencies and the other developing components of the DOE program, compose a coordinated attack on the uncertainties now limiting the ability to project future climatic change. Figure 1 suggests how the three major DOE programs are coupled, each depending on the other and benefitting from the other. An essential challenge for the coming year is to implement these notions of a coordinated program into an effective and active effort.

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Reference

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