**LDRD Program
Final Report**

Director's Initiative

Earth System Modeling

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LDRD Program
Final Report

Director's initiative
Earth System Modeling

Principal Investigators: Michael MacCracken/Joyce Penner
Project Title: Earth System Modeling
Tracking Code: 92-DI-006

Objective

The objective of the Earth System Modeling Director's Initiative is to develop and test a framework for interactively coupling subsystem models that represent the physical, chemical, and biological processes which determine the state of the atmosphere, ocean, land surface and vegetation. Most studies of the potential for human perturbations of the climate system made previously have treated only limited components of the Earth system. The purpose of this project was to demonstrate the capability of coupling all relevant components in a flexible framework that will permit a wide variety of tests to be conducted to assure realistic interactions. A representation of the Earth system is shown in the Figure and its important interactions.

Figure. Basic components of a comprehensive Earth system model. The physical process that together control climate are divided into six major components. Each component encompasses a variety of physical process representations. Components are coupled by exchange of data that may be multidimensional. Only some of the principal coupling mechanisms are shown explicitly.

Milestones

The Earth System Modeling project has completed three years of work. Major tasks proposed in the ESM project are 1) development of a coupled model framework, 2) coupling of an atmospheric general circulation model (GCM) with an oceanic GCM, 3) understanding biogeochemical cycles, and 4) representation of vegetation/climate response. Below we describe the completed work in each of these areas.

1) Development of a Coupled Model Framework

In order to utilize the most up to date computational platforms, to enhance computational efficiency, and to make this more convenient to the scientific user several software tools were necessary. An Edit library was developed for maintaining currently active versions of the code. A File Interface library was developed to provide a flexible interface module for coupling codes. Lastly, a Database library was developed to permit intercomponent handing, managing, and converting of the large quantities of data implemented in coupled global calculations.

Software wrappers were developed to allow individual component models to interact with the framework. Parallel versions of the oceanic and atmospheric GCMs have been installed into the common framework to permit concurrent execution for coupled model experiments. The new 3-D atmospheric chemistry model IMPACT is also now capable of running under the framework as is the equilibrium terrestrial ecosystem component TERRA.

2) Ocean-Atmosphere Coupling

Tracer capability was added to both the Cartesian-coordinate and density-coordinate oceanic GCMs. Bomb ^{14}C uptake has been simulated in the both models and have been compared to observations. The group has shown through 3-dimensional model experiments that the apparent imbalance in the global bomb ^{14}C budget is significantly smaller than previously published 1-dimensional model studies had suggested. In addition, the sea-ice module was fully incorporated into the Cartesian-coordinate ocean GCM allowing for ice-albedo feedback representation in coupled model simulations.

3) Biogeochemical Cycles

The role of atmospheric deposition of nitrate to the ocean surface and its effect on primary productivity was investigated. Our results have suggested that this source of nitrogen as a nutrient in the ocean does not appear to be as important as previously thought. We have developed the

capability to treat large aerosols and their deposition and removal by precipitation in a more realistic fashion. This has allowed our study of the deposition of atmospheric iron to the ocean surfaces and its importance as a micronutrient to the biogeochemical cycles in the ocean. We now hope to assess whether programs that propose human input of iron to the ocean will encourage the sequestration of atmospheric CO₂.

We have developed and tested a CO₂ version of the global atmospheric chemical tracer model GRANTOUR along with producing a global version of the terrestrial biosphere model TERRA. Successful one-way coupling of these models has been fully tested using gridded seasonal ocean carbon fluxes that were developed from data. Nitrogen cycling has been incorporated into the TERRA model because it is usually considered the limiting nutrient in terrestrial ecosystems. Much of the nitrogen work was performed through collaboration by a graduate student from UCSB.

Climate Vegetation Coupling

Globalization of the equilibrium terrestrial ecosystem model TERRA has been completed. The Biosphere Atmosphere Transfer System model (BATS) was incorporated into the framework, as was TERRA. Coupled simulations utilizing this capability should allow future assessment of climate change on ecosystem survival as well as economic impacts on crops.

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