THERMOHALINE CIRCULATIONS AND GLOBAL CLIMATE CHANGE

[DOE Grant No. DE-FG02-90ER61019]

Annual Progress Report No. 2

Howard P. Hanson, Principal Investigator
Atmospheric and Climate Dynamics Program
Cooperative Institute for Research in Environmental Sciences
University of Colorado at Boulder 80309-0216

DOE/ER/61019--2
DE92 008796

Overview

This report, which occurs at the halfway-point of the 36-month research project, discusses research activities conducted under the auspices of DOE Grant No. DE-FG02-90ER61019 during the period 15 January 1991 - 14 January 1992.

Background

"Thermohaline Circulations and Global Climate Change" is concerned with investigating the hypothesis that changes in surface thermal and hydrological forcing of the North Atlantic, changes that might be expected to accompany CO_2-induced global warming, could result in ocean-atmosphere interactions' exerting a positive feedback on the climate system. Because the North Atlantic is the source of much of the global ocean's reservoir of deep water, and because this deep water could sequester large amounts of anthropogenically produced CO_2, changes in the rate of deep-water production are important to future climates. Since deep-water production is controlled, in part, by the annual cycle of the atmospheric forcing of the North Atlantic, and since this forcing depends strongly on both hydrological and thermal processes as well as the windstress, there is the potential for feedback between the relatively short-term response of the atmosphere to changing radiative forcing and the longer-term processes in the oceans. Work over the past 12 months has proceeded in several directions.

Model Development

As reported in last year in Annual Progress Report No. 1, the hybrid ocean circulation model was ported to both the Unicos-based Cray Y/MP at NCAR and the Sun processor at CIRES. Over the past twelve months, additional ports of the model were made to the i860 processor and to a DEC workstation. During model testing on these platforms, and then, during a test of a higher resolution version of the model on the Sun system, an unforeseen error in the code arose, associated with floating-point underflow in the mixed-layer calculation. We believe that this had not occurred on the Cray system due to its greater intrinsic precision than the smaller processors. Model development activities in the past year included fixing this program bug and making the model stable on these various processors.

In addition, a final choice of the geographic domain of the basin model was made, and the model code was altered to include the Atlantic basin from (nominally) 65°N – 20°S, including the Gulf of Mexico and the Gulf of Guinea. The northern end of the model now corresponds to the more realistically to the ridge across Iceland between Greenland and Northern Europe, over which ridge the cold water from the Norwegian Sea flows into the North Atlantic. Benchmark testing of this new basin model is in progress.

Data Sets

Much of the P.I.'s time over the past year has been spent assembling the basin-model forcing data set. A preliminary version of this forcing set was discussed at a seminar at the University of Miami in March, 1991; a more complete version is the subject of a presentation at the International COADS Workshop in January, 1992 in Boulder. On useful result of this work has been the development of a method from which preferential sites for deep mixing can be deduced from the surface data, given a climatology of the mixed-layer depth. This ''mixing potential'' represents the combined effects of wind and thermohaline mixing processes and indicates the times and places where the mixed layer may be expected to be deepest in winter and early spring.

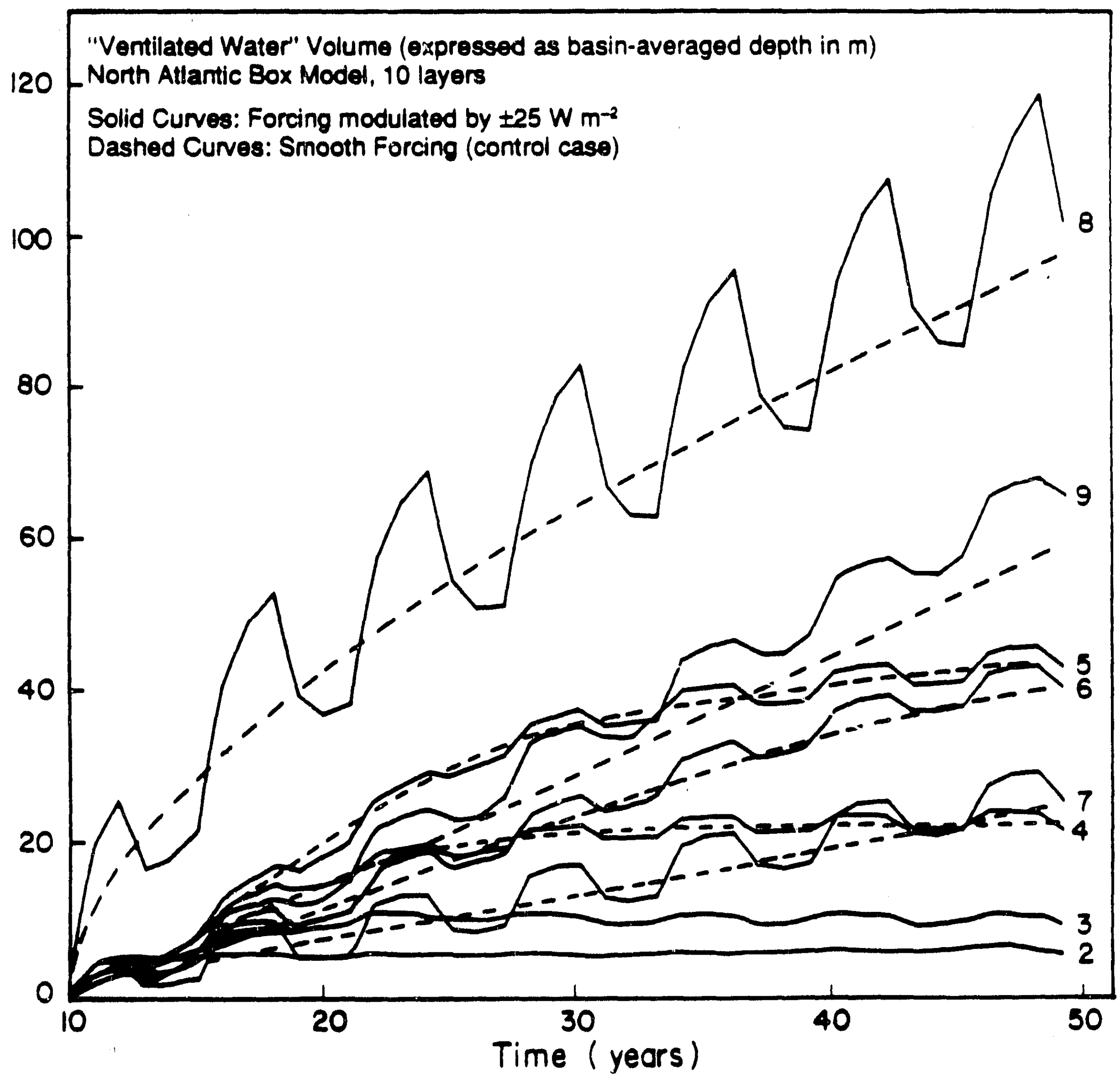
Two other conferences were attended in the past year by the P.I., the Second Scientific Meeting of The Oceanography Society (St. Petersburg, March, 1991) and the (combined) Fifth Conference on Climate Variations and Eighth Conference on Atmospheric and Oceanic Waves and Stability of the American Meteorological Society (Denver, October, 1991). Discussions with other scientists at these meetings were extremely useful as regards the strategy for assembling the forcing data set; in particular, the surface fluxes of radiation and fresh water (via solar and infrared radiation and precipitation) would seem to be a vexing problem for *all* ocean modelers. Because the fresh water flux along the boundaries of the Atlantic from the various rivers (in particular, the St. Lawrence, the Mississippi, the Amazon, the Congo, and the Rhine) is so large, the use of a zonally averaged prescription for freshwater input is less that realistic. If zonal variability in precipitation and runoff is to be included in the model forcing, then so should zonal variability of radiation be. This is being included in the model forcing by use of the J. Oberhüber's extensions of the COADS. Even though these radiation fields are based on empirical formulae, they are being used be a large enough cross-section of the ocean modeling community to make they a *de facto* standard.

At no cost to the grant, the P.I. also attended a workshop held under the auspices of the Jason group in La Jolla, CA (in July, 1991), which was contracted by DOE to examine the CHAMMP plans. A seminar on the hybrid model, and on our forcing and modeling plans, was presented, and results from the box version of the model were shown and discussed.

Other work regarding data set analysis during the past year included submission and revision of the manuscript ''Great Lakes Ice Trends; it has now been accepted for publication at the *Bulletin of the American Meteorological Society* (it is scheduled, with a photograph for the magazine cover, for the May, 1992 issue). This paper is of relevance to the project because one aspect of the data presented involves the outflow of the St. Lawrence. The paper discusses how, over the past 30 years, the timing of the spring runoff has shifted, slightly, toward earlier in the spring; this shift is consistent with the earlier departure in the spring of ice from the Great Lakes over the same time period. A preprint of the manuscript is attached.

Model Diagnostics

Although much of the past year was spent in the activities described above, three important areas of model diagnostics were also given attention. The visualization work progressed in two of these areas: a computer-controlled VCR was acquired (to supplant the manually-controlled VCR discussed last year) and software was developed to produce videos of the model's dynamical behavior. In addition, the research assistant (Mr. Hoge) has been working on a workstation graphics interface to depict model output without extensive low-level programming; this will be extremely useful to browse model output when production begins.



Finally, we have begun to test model sensitivity to various idealized forcing scenarios, and are able to present a preliminary result of one of these. This examines the model response to climate variability, both present and future, by simply perturbing the annually averaged radiative forcing by ± 25 W m^{-2} every 3 years (that is, for the first 3 years of a run, the radiative forcing is uniformly increased by 25 W m^{-2}; for years 4-6 it is decreased by that amount, then increased for 3 years, etc.). The figure above compares the model's behavior for this case vs. the case of uniform (i.e., annually varying, but all years are identical) forcing in terms of the "ventilated" water in various model layers. "Ventilated" water is defined, using the artificial tracer in the model, by the appearance of tracer injected through the surface in places where the mixed layer does not reach. That is, water directly detrained from the mixed layer is not counted. Note, despite the cyclic variability of the variable forcing case, that the mean amount of tracer increases faster than in the uniform forcing case. This is an important result that validates the investigation of the hypothesis presented in the original proposal, because it shows that climate change and variability is important in modulating the amount of water that is injected into the deep ocean, and therefore that the feedback to climate may be non-negligible. The attached continuation request describes how we plan to pursue this new result in the last half of the project.

Summary

Work during the first half of this 3-year project has proceeded within a reasonably close approximation to the original schedule. The unforeseen model bug, that occurs only on 32-bit processors, and then only when high vertical resolution is used, has been fixed, so the model has been successfully ported to a total of four processors from its original development version. Other aspects of the model development, data analysis, and model diagnostics are on track. It remains to go into "production mode" and develop the range of experiments necessary to explore the hypothesized feedback in detail. The early result shown here, however, lends credence to the hypothesis. Plans for the next 18 months are described in the accompanying continuation request.

END

DATE
FILMED
4 / 28 / 92