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RESEARCH ISSUES

and Supporting Research
of the

National Program On

Carbon Dioxide,

Environment And Society

Fiscal Year 1980

January 1981

CO₂

Prepared by the
U.S. Department of Energy,
Assistant Secretary for Environment
for the Interagency Committee on
Carbon Dioxide and Climate

National Climate Program Office

OFFICE OF CARBON DIOXIDE AND CLIMATE

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CO₂

Prepared by the
U.S. Department of Energy,
Assistant Secretary for Environment
for the Interagency Committee on
Carbon Dioxide and Climate
Washington, D.C. 20545

National Climate Program Office

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TABLE OF CONTENTS

	Page
PREFACE	v
OUTLINE OF A NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY	vii
EDITOR'S NOTE	ix
TABLE OF PROGRAM SUMMARIES OF NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY	xi
RESEARCH CATEGORIES	
I. Research Issues in the Global Carbon Cycle	1
II. Research Issues in Climate Effects	89
III. Research Issues in the Effects of Climate Change and Carbon Dioxide Increase on the Environment	129
IV. Research Issues on Social, Political, and Economic Costs and/or Benefits of Global Environmental Change	165
V. Research Issues on the Amelioration of Global and Sectoral Impacts	193
VI. CO ₂ Review, Integration, and Evaluation (Assessment) Program	197

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PREFACE

Leadership responsibility for the National Climate Program's major concern for Carbon Dioxide, Environment and Society has been assigned to the Department of Energy (DOE). To support DOE, the National Climate Program Office has established, under authority of Section 5 (e)(2) of the National Climate Program Act, an Interagency Committee on Carbon Dioxide and Climate. This committee is chaired by the Director of the DOE Carbon Dioxide and Climate Research Division who has the responsibility for coordinating the planning and conduct of CO₂ research throughout the federal government.

The goal of the National Program on Carbon Dioxide, Environment and Society is:

To develop the ability to predict the agricultural, environmental, and societal consequences, both national and international, of increasing atmospheric concentrations of carbon dioxide with sufficient confidence to permit informed policy decisions to be made on the use and development of energy and other resources.

This report outlines and summarizes the research conducted in the United States under the auspices of the CO₂ program. The Program encompasses six primary categories (see the outline that follows) which, in turn, are divided into 18 research subcategories and 51 research issues. The research program was designed to describe the research which should be conducted regardless of institutional or even national sponsorship. Project descriptions have been collected and classified according to the research issue to which they most directly apply and have been inserted immediately following the applicable issue description. This provides, for the first time, a detailed view of the nation's effort in addressing the carbon dioxide question in FY 1980.

The material appearing under Research Categories I through IV is the direct result of two major workshops and considerable follow-on activity sponsored by the Department of Energy. The first Workshop, held in Miami in 1977, addressed the Global Effects of Carbon Dioxide from Fossil Fuels and dealt primarily with the carbon cycle and the effects of increasing carbon dioxide on climate. The second, held in Annapolis in 1979, dealt with the cascade of environmental and societal consequences resulting from a climate change and increase in atmospheric concentrations of carbon dioxide. Following each of these workshops, detailed papers were commissioned to develop scientific plans for the conduct of research to address the relevant issues. These plans were then assembled by a scientific directorate into a comprehensive plan which included both priorities and a suggested budget. The issue descriptions appearing in this report are a digest of material contained in the Comprehensive Plan.

One final note. Recognizing that the carbon dioxide issue is not only national, but global in scope, future issues of this document will contain descriptions of all CO₂-related research in all countries.

A NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

A NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY (Cont'd)

EDITOR'S NOTE

Agencies were asked to provide material on a project basis for research directly supporting the National Program on Carbon Dioxide, Environment and Society. For this purpose, "directly supporting" was defined as research which met one or more of the following criteria:

- a) research explicitly traced to a requirement in the CO₂ research plan;
- b) initiated indirect response to the climatic, environmental or societal effects of increasing atmospheric concentrations of CO₂;
- c) although initiated for some non-CO₂-related reason, research which has become primarily and centrally involved in the concern over the increasing atmospheric concentrations of CO₂;
- d) even if the research had not been taking place, it would have probably been started as a direct result of the interest in the increasing atmospheric concentrations of CO₂;
- e) research providing important information which will demonstrably contribute to the resolution of the CO₂ issue.

Projects have been classified, in cooperation with the agency representatives, according to the research category, research subcategory, and research issue they primarily addressed. Projects listed within each research issue are arranged alphabetically by title. Where a project clearly addressed more than one issue, this has been noted and cross referenced to the additional relevant research issue.

With regard to research budgets, the reference to participating and funding agencies included in the research category descriptions is intended to identify both agencies which are now supporting directly and indirectly-related research and to indicate those which potentially might support in the future

the type of research suggested.

Since the project reports are intended to emphasize the research being conducted, certain expenses such as shiptime and program development were not reported; therefore, the project reports for a particular agency do not necessarily represent the entire CO₂ effort of that agency. Nor do all the project reports included here represent the total effort. However, the summary budget table which follows does include all these expenses with totals. Additionally, when multi-year funding was indicated for a project, the figure was prorated for FY 1980 to give an approximate level of effort for that year. Single projects supported by more than one agency have been combined into single project reports. Finally, funds reported for FY 1981 are estimates. Funds reported for FY 1982 are reflected in the President's budget and should be used for planning purposes only.

The research issues appearing in categories I and II are extracted from "A Comprehensive Plan for Carbon Dioxide Effects Research and Assessment, Part I: The Global Carbon Cycle and Climatic Effects of Increasing Carbon Dioxide," DOE/EV-0094, August 1980. The issues in categories III and IV are extracted from "Environmental and Societal Consequences of a Possible CO₂-Induced Climate Change--A Research Agenda," a report by the American Association for the Advancement of Science, DOE/EV/10019-1, December 1980. These latter issues have not yet been developed to the point of becoming Part II of the Comprehensive Plan; therefore, certain elements such as milestones and budget have been left blank. Research categories V and VI are still in the early stages of development and they are displayed only to keep interested parties conversant with the overall program.

The assistance of Paula Keene, The Institute for Energy Analysis, Oak Ridge Associated Universities, in preparing this report, is gratefully acknowledged (Contract No. DE-AC05-76OR00033).

Program Summaries

National Program on Carbon Dioxide, Environment and Society (In thousands of dollars)

xi

	DOE			NASA			NOAA		
	FY 1980	FY 1981	FY 1982	FY 1980	FY 1981	FY 1982	FY 1980	FY 1981	FY 1982
Carbon Cycle									
Fluxes of CO ₂	3,263	3,796	4,717	—	—	—	250	408	387
Atmospheric Storage	100	300	300	—	—	—	1,022	1,000	1,000
Past Records of CO ₂	427	300	300	—	—	—	0	0	0
Models of the Carbon Cycle	<u>8</u>	<u>300</u>	<u>400</u>	—	—	—	<u>76</u>	<u>72</u>	<u>175</u>
TOTAL	3,798	4,696	5,717	—	—	—	1,348	1,480	1,562
CO₂ and Climate									
Modeling the Effects of CO ₂ Increase	704	1,200	1,900	100	100	100	950	950	950
Reconstruction of Past Climates	346	400	500	0	0	0	0	0	0
Climate Scenario Development	0	100	100	0	0	0	0	0	0
Evidence of Climate Change	<u>0</u>	<u>100</u>	<u>100</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
TOTAL	1,050	1,800	2,600	100	100	100	950	950	950
Effects of Climate Change and CO₂ Increase on the Environment									
.....	239	1,309	3,324	—	—	—	—	—	—
Social, Political and Economic Costs and/or Benefits of Global Environmental Change									
.....	208	875	960	—	—	—	—	—	—
Amelioration of Global and Sectoral Impacts									
.....	40	400	674	—	—	—	—	—	—
Review, Integration and Evaluation (Assessment)									
.....	<u>228</u>	<u>795</u>	<u>1,578</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>
PROGRAM TOTAL	6,024*	10,239*	15,303*	100	100	100	2,298	2,430	2,512
	NSF**			USGS			TOTALS		
	FY 1980	FY 1981	FY 1982	FY 1980	FY 1981	FY 1982	FY 1980	FY 1981	FY 1982
Carbon Cycle									
Fluxes of CO ₂	5,508	3,939	2,007	405	480	480	9,361	8,558	7,516
Atmospheric Storage	0	0	0	0	0	0	1,122	1,300	1,300
Past Records of CO ₂	172	185	145	60	65	65	659	550	510
Models of the Carbon Cycle	<u>170</u>	<u>250</u>	<u>250</u>	<u>5</u>	<u>15</u>	<u>15</u>	<u>259</u>	<u>637</u>	<u>840</u>
TOTAL	5,850	4,374	2,402	470	560	560	11,401	11,045	10,166
CO₂ and Climate									
Modeling the Effects of CO ₂ Increase	314	450	245	—	—	—	2,068	2,700	3,195
Reconstruction of Past Climates	25	0	0	—	—	—	371	400	500
Climate Scenario Development	0	0	0	—	—	—	0	100	100
Evidence of Climate Change	<u>0</u>	<u>0</u>	<u>0</u>	—	—	—	<u>0</u>	<u>100</u>	<u>100</u>
TOTAL	339	450	245	—	—	—	2,439	3,300	3,895
Effects of Climate Change and CO₂ Increase on the Environment									
.....	283	318	328	5	5	5	508	1,627	3,652
Social, Political and Economic Costs and/or Benefits of Global Environmental Change									
.....	—	—	—	—	—	—	208	675	960
Amelioration of Global and Sectoral Impacts									
.....	—	—	—	—	—	—	40	400	674
Review, Integration and Evaluation (Assessment)									
.....	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>228</u>	<u>795</u>	<u>1,578</u>
PROGRAM TOTAL	6,477	5,142	2,975	475	565	565	15,369	18,476	21,455

*Includes Management and Program Development Funds.

**NSF Figures for FY 81 and FY 82 Show Only Projection of Ongoing FY 80 Projects.

I. RESEARCH ISSUES IN THE GLOBAL CARBON CYCLE

A. Fluxes of CO₂

1. Industrial Sources
2. Organic Terrestrial Fluxes
3. Inorganic Fluxes
4. Air-Sea Exchange
5. CO₂ Exchange Between the Upper and Deep Ocean
6. Oceanic Sediments

B. Atmospheric Storage

1. Observations of Atmospheric CO₂

C. Past Records of CO₂

D. Models of the Carbon Cycle

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

A. Research Subcategory: Fluxes of CO₂

1. Research Issue: Industrial Sources

1. Significance: The combustion of fossil fuels for space heating, energy generation and, to a lesser extent, cement manufacturing and other industry constitute a prime anthropogenic source of atmospheric CO₂. Estimates of future anthropogenic CO₂ releases are the crucial first step for predictions of CO₂ impacts on the environment and society.

2. Program Description: Currently anthropogenic CO₂ is estimated on an ad hoc basis by the use of data collected by the United Nations. Some of these numbers are suspect and should be carefully analyzed. The carbon content, the combustion efficiency and other factors related to the conversion of numbers for fossil fuel production and consumption to CO₂ releases into the air must be continually reexamined since fuel stocks change with time. Future scenarios of energy usage, which also are perceived differently with time, should be assembled from other energy policy organizations and from in-hour analysis of the energy future of the world.

3. Priority: Maintaining a record of past and current emissions of industrial fossil fuel sources of CO₂. Improving the accuracy of the estimates. The maintenance of the emission record is relatively easy to perform and will be done virtually irrespective of its priority. Medium

Preparation of future world energy scenarios and their releases of CO₂. This function will mainly be performed for other reasons and by organizations funded from non-CO₂ related programs. Special scenarios for the CO₂ issue will be needed for sensitivity studies, etc. High

4. Participating and Funding Agencies: DOE, EPA, NOAA, NSF

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Review published energy scenario predictions, update past and current CO ₂ releases.	200
1981	Initiate energy scenarios focused on updating past and current CO ₂ releases.	200
1982	Issue report on future energy scenarios related to CO ₂ issue, update past and current CO ₂ releases.	250

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1983	Analyze and improve knowledge of sources of past and current CO ₂ releases. Prepare draft summary report.	250
1984	Issue a revised future scenario report, assist in preparing a CO ₂ status report, update past and current CO ₂ releases.	250

Carbon Dioxide Project Report

Project Title:

CO₂ Assessment, Emissions, Information
and Services

Task II--CO₂ Emissions

Principal Investigator/s:

Allen, Edward L.; Rotty, Ralph M.

Organization/s:

Institute for Energy Analysis/
Oak Ridge Associated Universities

Funding: FY 80 \$200K

Project Number:

2932

Project Monitor:

Slade, David H.
DOE, Carbon Dioxide
and Climate Division
301-353-4374

Project Summary

CO₂ Emissions. CO₂ emissions from fossil fuels use have increased at the historic rate of 4.3% per year. The Institute for Energy Analysis will make projections for fossil energy growth in various segments of the world and estimate CO₂ production for a range of scenarios including coal, synthetic fuels and shale oil.

Category: IAl

6

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

A. Research Subcategory: Fluxes of CO₂

2. Research Issue: Organic Terrestrial Fluxes

1. Significance: It is necessary to determine if the observed increase in atmospheric CO₂ concentration is a result of net changes in carbon stored in the biosphere as well as fossil fuel combustion and industrial activity. Current methods of predicting future CO₂ growth are based on validation assuming only fossil fuel consumption in the past. If there has been a significant biospheric contribution to CO₂ increases, then predictions of future CO₂ are in error, since they are based on incorrect carbon cycle models.

Furthermore, increased atmospheric CO₂ may lead to increased photosynthesis and enhanced carbon storage especially in forests. The amount of increased carbon that might be stored in the biosphere by CO₂ fertilization is important for carbon cycle models.

2. Program Description: Three promising possibilities for determining biospheric CO₂ sources have been suggested: (a) measurements of ¹³C/¹²C ratios in both tree rings (for the past history of biosphere changes) and in air to monitor current trends; (b) measurements of the reduction in atmospheric O₂; and (c) remote sensing of vegetation changes accompanied by ground-truth measurements to determine its carbon content. Other promising ideas can also be examined. Each technique should be investigated for feasibility. Subsequent research will depend on the outcome of these feasibilities.

Initial planning for controlled studies of plant response to increased CO₂ will begin in 1981. The initial studies will include laboratory experiments in growth chambers. Later studies will treat forest growth in enhanced CO₂ "natural" environments. Experiments will determine changes in water use efficiency as well as carbon storage. They will include plants grown under normal environmental stresses in addition to studies under optimal growth conditions.

3. Priority: Determination of net flux of CO₂ from the biosphere is a very high priority item. The first step is to investigate the feasibility of several of the proposed methods. Subsequent priorities and funds will depend on the outcome of these feasibility studies. It is planned to pursue more than one line of research.

a) Carbon isotope studies to remove some of the uncertainties in the interpretation of the ¹³C/¹²C ratios in tree rings, coral rings, and present atmosphere. High

b) Precise measurements of changes in atmospheric O₂. High

c) Detection of changes in CO₂ (inorganic carbon) in the oceans. High

d) Measurement of changes in terrestrial biomass (including soils) by satellite sensing and/or in-situ observations. High

e) Studies of plant response to increased CO₂. High

4. Participating and Funding Agencies: DOE, DOA, NASA, NOAA, NSF

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Determine feasibility of items a-d; begin collection of samples for O ₂ , continue work previously started for items a and c.	700
1981	Select methods for intensive effort. Begin measurement phase.	1,500
1982	Continue measurements.	2,500
1983	Continue measurements. Assess results and desirability and need for using other approaches. Prepare draft summary report.	3,000
1984	Continue measurements. Complete summary report on findings to date.	3,000

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$31KDetermination of Atmospheric
CO₂-O₂/N₂ Molecular Ratio

Principal Investigator/s:

Project Number:

Tans, P. P.; Bloom, S. D.;
Muller, R. A.

3642

Organization/s:

Project Monitor:

Lawrence Berkeley Laboratory

Beadle, Robert W.
DOE, Pollutant Charac-
terization and Safety
Research Division
301-353-3764

Project Summary

The rise in the atmospheric CO₂ concentration due at least in part to the combustion of fossil fuels is expected to have a profound impact on the climate everywhere on earth. The credibility of current predictions of the future rise of atmospheric CO₂ is seriously impaired by the fact that the present CO₂ budget does not seem to be in balance. Very precise measurements of changes in the global atmospheric O₂/N₂ ratio in the course of a few years could provide the key to the solution of the "missing CO₂" problem.

The technique proposed herein is Raman scattering from ¹⁶O₂ and ¹⁴N₂ molecules. Advantages are that O₂, N₂, and CO₂ can be determined simultaneously in the same sample, and that the technique is nondestructive and nonconsumptive. This greatly facilitates inter-sample and sample-standard comparisons as well as taking much of the burden from the rigorous stability requirements of the experiment. Furthermore, it can yield count rates that are high enough to enable us to achieve the necessary precision.

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$150K

The Effect of Changes in Terrestrial Carbon
Pools on the CO₂ Content of the Atmosphere:
A Pilot Study in the Use of Satellite Imagery

Principal Investigator/s:

Project Number:

Woodwell, George M.; Hobbie, J. E.; Peterson,
B. J.; Melillo, J. S.; and Shaver, G. R.

8171

Organization/s:

Project Monitor:

The Ecosystems Center, Marine Biological
Laboratory

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

The research question is "What is the role of biota in CO₂ exchanges with the atmosphere; is it a source or sink?" The broad research objective is to estimate changes of carbon content of vegetation and soil primarily for forested ecosystems. Specific objectives are:

- 1) To develop techniques for use of satellite imagery in identification and classification of land-use and vegetation;
- 2) To develop techniques for use of satellite imagery in determining changes in the mass of carbon in vegetation;
- 3) To develop techniques for use of satellite imagery in determining changes in the mass of carbon in soils.

The main approach is to apply existing remote sensing (RS) techniques to estimate changes of biomass and soil carbon in relation to identifiable land management practices and as a result of successional changes following disturbance. A pilot study will determine carbon mass and temporal changes from RS data and ground-truth ecological measurements. The pilot study is essentially a test of the concept and a determination of whether RS approaches are feasible, and it will attempt to assess the accuracy of vegetation change estimates in the content of global carbon exchanges among atmosphere, biosphere, and oceans.

Validation of RS estimates is proposed for both temperate and tropical forest types, the former in the state of Maine because of accessibility and availability of ancillary information. Techniques developed from the temperate forest pilot study will be further tested at a tropical site in either Central or South America. There is a crucial need to understand characteristics of

carbon storage and sequestering or release from managed tropical forests in order to resolve the issue of whether the biota is a source or sink for carbon (and of what magnitude).

Two groups have assembled their talents to investigate this problem; a team of ecologists with knowledge and experience in measuring terrestrial biomass; and a team of remote sensing specialists with experience in using LANDSAT imagery to examine environmental problems. George Woodwell of the Ecosystems Center (MBL) is coordinating both parts.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$210K

Global Carbon Cycles and Climatic Risks

Principal Investigator/s:

Project Number:

Olson, J. S.

1669

Organization/s:

Project Monitor:

Oak Ridge National Laboratory

Osburn, William O.
DOE, Ecological Research
Division
301-353-4903

Project Summary

The purpose of integrated assessment relating carbon cycles to climate is to reduce uncertainties about the future, eventually showing how the impacts of climatic change on ecosystems and ecological exchanges of CO₂ may alter the existing global cycle of carbon, hence the further changes in CO₂ and climate, and further ecosystem (and social) changes that collectively constitute a causal feedback loop on the global system. The approach is from (1) tests and improvements of carbon cycle and time series data and global models, through (2) projections of credible climatic impact on crops, forests, water balance, physiological feedbacks to global CO₂ and future fuel scenarios, toward (3) iterated environmental assessments (in cooperation with Oak Ridge Associated Universities, social sciences groups, and individual collaborators from elsewhere).

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$25KMeasurements of Atmospheric O₂:
Gravimetrics

Principal Investigator/s:

Project Number:

Hughes, E.

Organization/s:

Project Monitor:

National Bureau of Standards jointly with NOAA

Machta, Lester
NOAA, Air Resources
Laboratory
301-427-7609

Project Summary

Support for the development of an ultra-precise technique using gravimetric principles for determining changes in atmospheric O₂ concentration. Such measurements could help infer the net amount of non-fossil fuel additions to atmospheric CO₂. NOAA will supply samples collected near Antarctica to minimize seasonal variability.

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$50KMeasurements of $^{13}\text{C}/^{12}\text{C}$ in the
Atmosphere

Principal Investigator/s:

Project Number:

Friedman, I.

Organization/s:

Project Monitor:

U.S. Geological Survey

Machta, Lester
NOAA, Air Resources
Laboratory
301-427-7609

Project Summary

Monitoring of ratio of C-13 isotope to C-12 in the atmosphere. The ultimate purpose is to infer from such measurements the net amount of CO_2 coming from non-fossil fuel sources into the air.

Category: IA2

Carbon Dioxide Project Report

Project Title: Preliminary Characterization of Soil Matter Quantity and Quality in Northern Alaska Funding: FY 80 \$40K

Preliminary Characterization of Soil
Matter Quantity and Quality in
Northern Alaska

Principal Investigator/s:

Project Number:

Miller, Philip C.; Everett, Kaye

8581

Organization/s:

Project Monitor:

San Diego State University

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

This is a subproject of an ongoing project "Research of Tundra Ecosystems and Their Potential Response to Energy Resource Development."* The purpose of the subproject is to characterize soil organic matter quantity and quality in Northern Alaska across a transects following the Yukon-Prudhoe haul-road from Fairbanks to the North Slope. Field studies will estimate the magnitude of carbon stored in organic and mineral soils to determine potential CO₂ emissions from disturbance on climate change in the Arctic.

Remarks: *Funded by Ecological Research Division,
DOE, at \$316K.

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$65KRole of Atmospheric Carbon
Dioxide in Arctic Tundra

Principal Investigator/s:

Project Number:

Billings, W. D.; Peterson, K. M.

DEB79-22191

Organization/s:

Project Monitor:

Duke University

Lance, John
NSF, Earth Sciences
202-357-7915

Project Summary

Increasing atmospheric CO₂ content may produce deleterious effects upon world climate. The role of the biosphere as a source or sink for atmospheric CO₂ is uncertain; the far north is probably a sink. As CO₂ concentrations continue to rise, global warming may occur which will be most evident in polar regions. Would a warmer climate lead to increased decomposition of peat deposits in arctic tundra exacerbating the atmospheric CO₂ problem? Also, what would be the ecological results of the loss of insulating peat to permafrost and ice-wedges in the tundra?

Frozen cores of tundra vegetation and soils will be collected from sites representing stages of the thaw-lake cycle. These will be subjected to a variety of controlled climatic conditions at the Duke University Phytotron. Here, we will measure carbon budgets of these cores of living plants and peaty soils. Replicates from several sites will be measured. Field and laboratory studies of peat decomposition are also proposed.

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$486K

The Role of Terrestrial Ecosystems and
Climatic Change in the Global Carbon
Cycle

Principal Investigator/s:

Project Number:

Van Hook, Robert; Olson, Jerry S.

DEB78-26772

Organization/s:

Project Monitor:

Oak Ridge National Laboratory

Lance, John
NSF, Earth Sciences
202-357-7915

Project Summary

Increased fossil fuel combustion, land clearing, and a large variety of other factors have led to what is presumed to be a "global carbon dioxide problem." At the very least, it is a perplexing issue impinged upon by virtually all facets of the physical environment and all types of living material. Currently, scientists are unable to account for much of the CO₂ supposedly released to the atmosphere, an issue of major scientific concern. The point has been repeatedly made that the biosphere's production of organic carbon is significantly higher than the geochemists generally recognize.

This research project will seek to quantify the role of terrestrial ecosystems in the balance and dynamics of the global carbon cycle and to estimate the effects of detectable climate change upon the distribution of carbon within such systems. The project is multifaceted, involving several institutions and a large number of scientists. Research methodologies and techniques will cover a broad spectrum including review and evaluation of extant data bases, field and laboratory experiments, large survey, paleoclimatology and palynology. It is expected that the work will eventually lead to much better definition of the role of terrestrial ecosystems, especially forests, as sources and/or sinks for carbon.

Category: IA2

Carbon Dioxide Project Report

Project Title: Successional Forest Stands As Sinks for Atmospheric Carbon Dioxide Funding: FY 80 \$103K

Successional Forest Stands As Sinks for
Atmospheric Carbon Dioxide

Principal Investigator/s:

Project Number:

Gates, David M.

7863

Organization/s:

Project Monitor:

University of Michigan

Osburn, William S., Jr.
DOE, Ecological Research
Division
301-353-4903

Project Summary

This project involves a series of steps to gather better information and make improved estimates of the response of northern temperate forests to increasing concentrations of CO₂. The steps proposed are summarized as follows:

- 1) Obtain field measurements of net photosynthetic rates of leaves (and bark where appropriate) on a diurnal basis throughout the growing season and relate this response to environmental factors such as CO₂ concentration, light intensity, temperature, and water availability.
- 2) Obtain field measurements of the diurnal variation of all plant parts and of the underlying soil throughout the year and relate this response to environmental factors.
- 3) Obtain basic information concerning rates of growth, primary production, and standing biomass in a variety of north temperate forests. We are finding the data base for this type of information at the Biological Station to be unique and very substantial.
- 4) Model forest tree photosynthesis and respiration using our whole leaf photosynthetic model which includes light and dark respiration of various tree parts including root and soil respiration. Develop a model for a whole tree and the underlying soil which is applicable to both diurnal and annual responses of forest trees.
- 5) Apply the whole tree model to trees forming a stand.
- 6) Relate the whole tree analytical model to the forest stand data obtained on the forest plots of the Biological Station.

- 7) Eventually extend the results of this work to other forest stands in North America and obtain information concerning the response of these forests to increased concentrations of atmospheric carbon dioxide.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$33KWorkshop on Flux of Organic Carbon
on the Oceans

Principal Investigator/s:

Project Number:

Stevens, Russell B.

8177

Organization/s:

Project Monitor:

National Academy of Sciences,
National Research CouncilDahlman, Roger C.
Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

The National Academy of Sciences, through the Division of Biological Sciences, proposes to organize a workshop to examine the feasibility of measuring the transport of particulate and dissolved organic matter by the world's major rivers to the oceans.

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$17K

Workshop on the Interrelationship Between the
Carbon Balance of Northern Ecosystems and the
Global Carbon Balance

Principal Investigator/s:

Project Number:

Miller, Philip C.

8324

Organization/s:

Project Monitor:

San Diego State University

Osburn, William S., Jr.
DOE, Ecological Research
Division
301-353-4903

Project Summary

Objective: Conduct a workshop to evaluate several propositions by giving estimates of the annual carbon flux per square meter, assessing quantitatively the role of factors controlling the annual carbon flux, and documenting the conclusions reached regarding the carbon flux.

Approach: A workshop will be held. The output will be a written report evaluating and quantifying the effect of increasing CO₂ concentrations on the wetland tundra and taiga, a research article (if timely) for publication, and a proposal for research (if necessary).

Category: IA2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$95KHawaiian Volcano Observatory
Mt. St. Helens Project

Principal Investigator/s:

Project Number:

Sato, M.; Greenland, P.;
Casadevall, T.; Harris, D.

Organization/s:

Project Monitor:

U.S. Geological Survey
Office of Geochemistry
and Geophysics,
Geologic DivisionSato, M.
USGS, Reston, VA
703-860-6600

Project Summary

Geochemists with the USGS Hawaiian Volcano Observatory and Mt. St. Helens project have taken particular interest in developing a budget of volatile emissions (SO_2 , CO_2 , Cl, F, H_2O , etc.) from the active volcanoes Kilauea, Mauna Loa, and Mt. St. Helens. SO_2 production is measured directly using a correlation spectrometer (COSPEC). Other volatile species such as CO_2 are calculated by ratio to SO_2 once the chemistry of the fume and condensate are determined using airborne conventional analytical techniques. CO_2 is also measured directly using an infrared technique. At Mt. St. Helens, about ten hours of flight time per week are devoted primarily to CO_2 flux measurements. This research has involved the cooperation of NOAA (Mauna Loa Observatory), CNR (France), Dartmouth College, and the University of Hawaii (Institute of Geophysics). The goal is to develop an accurate yet simple method for making complete volatile emission budgets for any active volcano of interest. This method could lead to a statistically accurate estimate of global volcanic CO_2 emanations.

Category: IA2

Note: For additional research supporting this issue refer to:

Title

Category

Worldwide CO₂-Rich Discharges and Their Origins

IA3

24

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

1. CO₂ Research Category: The Carbon Cycle

A. Research Subcategory: Fluxes of CO₂

3. Research Issue: Inorganic Terrestrial Fluxes

1. Significance: The reaction of atmospheric CO₂ with exposed carbonate rocks and calcareous soils may affect the flux of CO₂ into and out of the air. Questions of deep leaching of bicarbonate and possible influences of acidic precipitation need to be better known.

2. Program Description: A preliminary study of the magnitude of the exchangeable carbonate pool and its chemical dynamics is needed to determine the need for further research on the role of inorganic terrestrial carbon in the short-term carbon cycle.

3. Priority: Preliminary estimates of the magnitude of the pools and fluxes.
Medium

4. Participating and Funding Agencies: USDA, USGS, DOE, NSF

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	None.	
1981	Initiate preliminary studies.	100
1982	Determine the need for further efforts.	200
1983	Continued effort if required. Prepare draft summary report.	200
1984	Evaluate current studies.	200

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$60K

Brush Fire Project

Principal Investigator/s:

Project Number:

Crutzen, Paul

Organization/s:

Project Monitor:

National Center for Atmospheric Research

Hecht, Alan
NSF, Atmospheric
Sciences
202-357-9892

Project Summary

Large-scale savannah and brushland fires associated with shifting agriculture in South America are responsible for a major source of trace gases to the global atmosphere. It is proposed to make research flights in the region of these fires and to measure the concentration of CO₂, CO, CH₄, N₂, H₂, CH₃Cl, CH₃CCl, COS, NO, and O₃ and to collect filter samples to investigate aerosol graphitic carbon and plant nutrient elements. The flights will be made in east central Brazil in a region where this type of burning is commonly practiced at the end of the dry season in the month of August.

On the ferry to and from the base of operations in Brazil tropospheric profiles will be determined for CO₂, CO, CH₄, NO₂, O₃ and additional stratospheric overburdens of HNO₃, CF₂Cl₂, HF and H₂O will be determined.

Remarks: Joint project with Brazil.

Category: IA3

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$65K

Global Geochemical Cycles of the Elements

Principal Investigator/s:

Project Number:

Mackenzie, Fred T.; Lerman, Abraham;
Garrels, Robert M.

EAR76-12279

Organization/s:

Project Monitor:

Northwestern University

Lance, John
NSF, Earth Sciences
202-357-7915

Project Summary

This project concerns studies of the geochemical cycles of carbon, nitrogen, phosphorus, sulfur, oxygen and certain trace elements. The object is to determine quantitatively their distribution and migration in the upper lithosphere, soil, atmosphere, continental and oceanic waters, biosphere, and sediments. The pre-man stage of cycling of these elements will be determined from data from the geological and oceanic record. This stage will be used as a baseline on which to assess man-induced perturbations on the cycling of these biologically important elements. Geochemical cycles of the elements will be portrayed using compiled data on the important geochemical reservoirs and inter-reservoir fluxes and mathematical modeling of the cycles. This will allow the formation of predictive models that will be useful in assessing geochemical processes in the geologic past, present, and future. This is a project involving long-term effort and is of first-order importance to geochemistry.

Category: IA3

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$220KWorldwide CO₂-Rich Discharges
and Their Origins

Principal Investigator/s:

Project Number:

Barnes, I.

Organization/s:

Project Monitor:

U.S. Geological Survey
Western Region Research Group
Water Resources DivisionBarnes, I.
USGS, Menlo Park, CA
415-323-8111 ext. 2511

Project Summary

This project locates CO₂ discharges as gas or in soda springs throughout the world. The rate and nature of the CO₂ discharge is measured, and the amount discharged to the air is distinguished from that retained by travertine deposits or algal growth. Stable carbon isotope analyses are used to determine the ultimate source (mantle or new, metamorphic or reissued) of the carbon. This project also participates in the monitoring of CO₂ released from Mt. St. Helens and other active volcanoes throughout the world.

Remarks: Also applies to IA2.

Category: IA3

I, A, 4

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

A. Research Subcategory: Fluxes of CO₂

4. Research Issue: Air-Sea Exchange of CO₂

1. Significance: The oceans are the main sink for excess CO₂ in the atmosphere. Some regions of the ocean transfer CO₂ to the air while other regions of the ocean take up CO₂. The determination of these regions and the direction and amount of the net exchange is helpful to global modeling of the CO₂ cycle.

2. Program Description: The CO₂ concentration gradient across the air-sea interface has and will be measured from ships of opportunity. This only gives the sense of the transfer not the amount. Techniques for measuring the amount of flux could include eddy correlation measurements on fixed platforms. When accompanied by measurements of the concentration of CO₂ between the air and water, the correlation technique may be generalized to the open oceans. The buffering capacity of the ocean for CO₂ and other relevant chemical aspects will be measured at various locations. Exchange processes will also be studied using ¹⁴CO₂ and ²²²Rn as tracers. Transfer across sea ice should also be considered.

3. Priority: Some continuation of the present investigations of transfer across the air-sea boundary is planned. Much of the work would be incidental to other oceanic observations. Direct measurements of fluxes should be investigated briefly for their feasibility. The investigations have a low priority except where they can be carried out easily and with relatively little expense in connection with higher priority items.

Continued use and development of the ¹⁴C and ²²²Rn technique is anticipated. Medium

4. Participating and Funding Agencies: DOE, NSF, NOAA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Assess the need for special flux measurements over the sea. Obtain CO ₂ gradient measurements across the air-sea interface on ships of opportunity.	200
1981	Measure fluxes with either special equipment and/or by air-sea gradients on ships of opportunity. Initiate study of all information bearing on the rate, the diurnal and seasonal and the geographical variations of CO ₂ exchanges across the air-sea interface.	250

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1982	Continue flux measurements and study existing information.	300
1983	Continue flux measurements. Prepare a comprehensive report on knowledge about the air-sea exchange. Prepare draft summary report.	300
1984	Reassess the needs for further measurements and analyses.	300

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$202KCarbon Dioxide in Arctic
and Sub-Arctic Regions

Principal Investigator/s:

Project Number:

Gosink, Thomas A.; Kelley, John T.

8415

Organization/s:

Project Monitor:

Geophysical Institute,
University of AlaskaOsterberg, Charles L.
DOE, Ecological Research
Division
301-353-3035

Project Summary

This is the first of a three-year effort to define the role of the arctic oceans, sea ice, tundra, taiga, high latitude ponds and lakes, and polar anthropogenic activity on the carbon dioxide content of the atmosphere. Due to the large physical and geographic differences between the two polar regions, a comparison of CO₂ source and sink strength of the two areas is also planned.

The arctic and subarctic regions represent nearly 10 percent of the northern hemispheric surface, half of which is Arctic Ocean and tundra; global atmospheric diffusion models for CO₂ do not work well for the Arctic where winter-summer differences are the largest in the world. There is a substantial amount of data on measured atmospheric CO₂ levels of the arctic environment, but there is a significant lack of information for sources and sinks, particularly with respect to seasonal and geographic rates of exchange. Our present information shows that annual sea ice and frozen tundra are not sealed, but evolve significant quantities of carbon dioxide throughout the winter, and that the Arctic is a significant net annual source of carbon dioxide to the atmosphere.

Data on CO₂ levels and exchange rates will be the basis for the understanding of the loading of the arctic atmosphere with carbon dioxide. This information will be used to attempt to quantify the physical processes of transport and diffusion as used in contemporary models.

During the first two years, missing seasonal and geographic data on CO₂ levels will be acquired in the Arctic for the atmosphere, the tundra, the oceans, and sea ice. This will be accomplished by means of aircraft, foreign and domestic research vessels, and operations from ice islands. In the third year, comparative Antarctic studies will be made, but the primary emphasis will

be on synthesizing all source and sink terms and rates for use in conceptual and numerical models.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$35KCO₂ Flux Verification Studies

Principal Investigator/s:

Project Number:

Hicks, Bruce B.; Wesley, Marvin L.

3219

Organization/s:

Project Monitor:

Argonne National Laboratory

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

The steadily increasing trend in global atmospheric carbon dioxide concentration is now well documented, but the relationship with increased combustion of fossil fuels remains controversial. One major factor controlling the atmospheric response to increasing rates of carbon dioxide emission is the net transfer to oceans. Fluxes of carbon dioxide to and from oceans can be calculated by several methods, each of which assumes that the rate of exchange between the lower atmosphere and the well-mixed, upper ocean is limited by a large physical resistance to transfer in a thin, quasi-laminar layer immediately beneath the water surface. The present program will evaluate alternative techniques for parameterizing the behavior of this interfacial sublayer. Predicted carbon dioxide fluxes will be compared with direct measurements obtained by a micrometeorological eddy-correlation technique. Equipment required is already available except for a perfected carbon dioxide sensor with suitable characteristics. The experimental program will emphasize observations in moderate to strong winds, including the case of breaking waves, to evaluate the physical and chemical processes that effect the sublayer resistance. Initial equipment trials will be conducted over land, and subsequent measurements will be made over southern Lake Michigan.

Category: IA4

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$11K

Carbon Dioxide Measurements in the
Equatorial Pacific

Principal Investigator/s:

Project Number:

Weiss, Ray F.

8236

Organization/s:

Project Monitor:

Scripps Institute of Oceanography

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

Continuous shipboard measurement of the concentration of CO₂ in marine air and its partial pressure in the surface ocean water of the central tropical Pacific will be made. This represents a major portion of a cooperative effort by several laboratories to study the exchange of carbon dioxide between the atmosphere and the sea during the Norpax Equatorial Experiment. The measurements will be made by a new gas chromatographic technique which provides exceptionally accurate analyses of CO₂ in small samples. In addition, the instrument will determine concentrations of nitrous oxide and methane in the same samples.

Category: IA4

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$40K

Enzymatic Enhancement of the
Carbon Dioxide Flux Across the
Air-Sea Exchange

Principal Investigator/s:

Project Number:

Johnson, Kenneth S.

OCE80-08233

Organization/s:

Project Monitor:

University of California,
Santa Barbara

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

This project is an investigation of the role of natural catalysts in enhancing the flux of carbon dioxide across the sea surface. It is suggested that there may be an enzymatic enhancement of the CO₂ flux, between the ocean and the atmosphere. A survey of literature data indicates that such an enhancement is feasible at extremely low levels of carbonic anhydrase, the enzyme responsible for the enhancement. However, no systematic investigations of this problem have been made, despite its crucial importance. Preliminary measurements to determine the activity of carbonic anhydrase in seawater have been carried out. The results indicate that enough enzyme is present in the sea surface lamina layer to result in at least a 7 percent enhancement of the CO₂ flux in the samples examined. The technique which will allow very accurate determinations of the enhancement of the CO₂ flux under oceanic conditions will be developed. This technique will be used to quantitatively establish the relationship between carbonic anhydrase concentration and CO flux enhancement.

Category: IA4

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$59K

Investigation of the Surface Water $p\text{CO}_2$
in the Equatorial Pacific Ocean

Principal Investigator/s:

Project Number:

Takahashi, Taro

7867

Organization/s:

Project Monitor:

Lamont-Doherty Geological Observatory

Osterberg, Charles L.
DOE, Ecological Research
Division
301-353-3035

Project Summary

We have been investigating primarily the seasonal and geographic variations of the partial pressure of CO_2 ($p\text{CO}_2$) exerted by the surface water of the equatorial Pacific Ocean. The samples were collected during the FGGE/NORPAX shuttle cruises between Tahiti (18°S) and Hawaii (21°N) across the equator along the 150°W and 158°W meridians. Air samples were also collected during the cruises for investigation of the seasonal and geographic variations of the CO_2 concentration in marine air at sea level. Since the estimated net flux of CO_2 being transferred from the equatorial Pacific to the atmosphere corresponds to about one-half of the current fossil fuel CO_2 discharge rate, knowledge of the variability of the equatorial water $p\text{CO}_2$ is important for our quantitative understanding of the CO_2 budget in the air-sea system.

The sampling program was initiated during FGGE Leg 3, which started on April 3, 1979, at Tahiti, and ended on May 3, 1979, at Hawaii. The second series of sampling was undertaken during Leg 5, June 19 through July 14, 1979. The fourth series of samples was collected during January 1980.

In this project, we made one last sampling cruise in April 1980, so that the data set obtained from this program covered a complete 12-month period starting from April 1979 and ending in April 1980. Approximately 100 samples for the surface water $p\text{CO}_2$ and the atmospheric CO_2 studies were collected, and they were analyzed immediately after completion of the cruise. Based upon these data, we were able to characterize the magnitude of the seasonal variation in the surface water $p\text{CO}_2$ in this strong oceanic CO_2 source area. We plan to further investigate the causes for the high $p\text{CO}_2$ equatorial water and its seasonal variability.

With additional atmospheric CO_2 concentration data from the subsequent cruises, we will be able to elucidate the nature of the seasonal and meridional variations in the atmospheric CO_2 concentration at sea level. These data will

be incorporated into a two-dimensional model for the distribution of atmospheric CO₂ being developed at our laboratory.

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$100K</u>
North Pacific Experiment (NORPAX): Exchange of Equatorial Pacific Waters from Tritium Studies	
Principal Investigator/s:	Project Number:
Fine, Rana A.; Ostlund, H. Gote	OCE78-22120
Organization/s:	Project Monitor:
	Collins, Curt NSF, Ocean Sciences 202-357-7906

Project Summary

This project is part of the North Pacific Experiment (NORPAX). The long-range goal of NORPAX is to understand fluctuations in the upper layers of the Pacific Ocean with time scales of months to years and space scales in excess of 1,000 kilometers, and the relationship of these oceanographic fluctuations to the overlying and adjoining atmosphere. Achievement of this goal should eventually lead to improved weather/climate prediction for both the Pacific Ocean and North America.

One major component of NORPAX is a coordinated field program to determine the space and time variability of the density and velocity fields in the upper layers of the Equatorial Pacific current system. This field program occurred between February 1979 and July 1980 and involved the efforts of a number of scientists. Measurements were made from ships, airplanes, and moored and drifting instruments.

This grant involves the logistics and analysis of tritium on the Equatorial shuttle. Initially, several hundred samples were taken on two legs of the shuttle. Tritium and hydrographic data will be used to estimate the exchange rates between equatorial current systems; and the quantitative importance of meridional transport to the data will be used to estimate the exchange rates between equatorial current system and the quantitative importance of meridional transport to the upwelling process.

Category: IA4

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$360K

North Pacific Experiment (NORPAX):
A Transequatorial Shuttle Experiment

Principal Investigator/s:

Project Number:

Wyrтки, Klaus

OCE78-20719

Organization/s:

Project Monitor:

University of Hawaii

Collins, Curt
NSF, Ocean Sciences
202-357-7906

Project Summary

This project is part of the North Pacific experiment. The goal of NORPAX is to understand long-period, large-scale ocean atmosphere coupling. The main objective of the equatorial shuttle experiment is to develop the scientific basis for a monitoring system for the Equatorial Pacific--a monitoring system which indicated that the strength of the equatorial currents and the trade winds would contribute to seasonal and long-range forecasts for continental North America.

The shuttle experiment consisted of 16 consecutive hydrographic surveys between Honolulu and Tahiti commencing in January 1979. The shuttle determined if (1) temperature sections can be used to derive useful indices of the strength of equatorial currents; (2) sea level observations can be used to monitor low frequency variations of equatorial currents; and (3) a monitoring network can be designed from XBT sections and sea level stations for continued surveillance of the changing Equatorial Pacific.

Category: IA4

The oceanic uptake of CO_2 from fossil fuel is attended by increasing total dissolved carbon and may be accompanied by increasing alkalinity if solid carbonates are attacked and dissolved by the more acidic waters resulting from the uptake. The Laboratory will measure total carbon and alkalinity in subsurface ocean waters, collected a depth of 500 meters or more during oceanic expeditions, to establish accurate base-line data for possible future detection of secular changes.

The Laboratory will carry out detailed model studies of the time dependent global carbon cycle in order to improve on predictions of the fraction of CO_2 from industry which will accumulate in the air during the next several hundred years, and the long-range climatic and environmental impacts of this accumulation.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$73K

Trace Gases in the Ocean and Atmosphere

Principal Investigator/s:

Project Number:

Weiss, Ray F.

OCE78-09038

Organization/s:

Project Monitor:

Scripps Institution of Oceanography

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

This proposed investigation is for continued research on the distribution of trace gases in the atmosphere and sea. Special emphasis is being placed on the study of nitrous oxide, which has an important controlling influence on the stratospheric ozone layer. The results of recent high-precision measurements of N_2O in the atmosphere covering a wide variety of locations show that the concentration of tropospheric (0.16% per year) increase attributed to combustion or fertilizer denitrification sources. Measurements of N_2O in ocean surface waters have also been obtained, and indicate that the sea is a less significant source of N_2O than has been suggested by some earlier data. Further atmospheric measurements and oceanic studies are to be conducted in the following year to better refine our understanding on the sea acting as a source or sink of atmospheric N_2O .

Category: IA4

Note: For additional research supporting this issue refer to:

Title

Category

Geological Perspectives on Global CO₂

IA6

44

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I CO₂ Research Category: The Carbon Cycle

A Research Subcategory: Fluxes of CO₂

5. Research Issue: CO₂ Exchange Between Upper and Deep Ocean

1. Significance: The transfer of CO₂ from the surface ocean to deeper waters is the rate-limiting step in the loss of CO₂ from the air. Improved knowledge of this rate of transfer is necessary to determine the ocean's ability to absorb excess CO₂ in the time scale of decades to centuries.

2. Program Description: Tracers such as ³H and its daughter ³He, ¹⁴C and ⁸⁵Kr from nuclear activities, cosmogenic ³⁹Ar, and fluorocarbons have been injected into the atmosphere by nature and from man's activities and then transferred to the surface waters of the oceans. Their subsequent distributions in the oceans provide valuable information on oceanic mixing and transport which can be used to model the transfer of excess CO₂ into the deeper oceans. In addition, changes, if any, in the rate of transfer of carbon by biological processes shall be assessed.

3. Priority: Engage in transient tracer experiment to form the basis for ocean transport modeling. High

Determine possible changes in organic transfer and sequestering of carbon.
Medium

4. Participating and Funding Agencies: NSF, DOE, NOAA

5. Milestones and Budget

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Continue purchase and development of field equipment. Shakedown cruise in North Atlantic.	2,000
1981	Conduct major sampling activity in North Atlantic.	2,200
1982	Sample analysis and data interpretation. Initiation of ocean transport modeling.	1,500
1983	Continue data analysis and interpretation. Prepare for southern ocean cruise. Prepare draft summary report.	1,500
1984	Undertake transient tracer program in southern oceans. Complete survey of state of knowledge on ocean modeling.	3,000

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$94KBomb Radiocarbon Sections Along the
Hawaii-Tahiti Shuttle Track

Principal Investigator/s:

Project Number:

Stuiver, Minze

8166

Organization/s:

Project Monitor:

University of Washington

Beadle, Robert W.
DOE, Pollutant Charac-
terization and Safety
Research Division
301-353-3764

Project Summary

By taking advantage of the equatorial crossings made by the NORPAX group during 1979, plans are to study the equatorial dynamics of the Pacific Ocean. The dynamics of equatorial upwelling are intimately connected with aspects of modeling of the oceanic uptake and distribution of fossil fuel CO₂.

The study will be made by measuring the spatial pattern and temporal history of bomb radiocarbon in the equatorial ocean and eastern boundary currents.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$24KCalcium Carbonate and Organic
Carbon in the Oceans

Principal Investigator/s:

Project Number:

Chen, Chen-Tung

OCE79-19559

Organization/s:

Project Monitor:

Oregon State University

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

The increase in atmospheric carbon dioxide resulting from the combustion of fossil fuels is of great concern because of its many potential environmental influences. A major sink for this carbon dioxide is in the ocean. In order to have a predictive knowledge of how fast the oceans will be able to remove carbon dioxide from the atmosphere and what the effects will be on oceanic systems, it is necessary to clearly understand the chemical controls on the distribution and dynamics of the carbonic acid system in the deep oceans. In addition to carbon dioxide transport by mixing dissolved components, carbon dioxide can be added to deep-sea water by the oxidation of organic matter and the dissolution of calcium carbonate. In order to separate these two processes and determine their relative significance, precise total carbon dioxide, alkalinity and calcium concentration data must be used to construct and test mathematical models. Measurements of calcium concentrations relative to salinity will be performed on seawater samples collected during the GEOSECS programs. These data will be combined with existing GEOSECS total carbon dioxide and alkalinity in mathematical models. Based on the results of these calculations, the importance of different processes influencing carbon dioxide distribution in various oceanic regions will be determined.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Coral Growth Rings and the Temporal
History of Nuclear $^{14}\text{C}/\text{C}$ and $^{90}\text{Sr}/\text{Sr}$
in the Surface Ocean

Funding: FY 80 \$97K

Principal Investigator/s:

Broecker, Wallace S.; Fairbanks, Richard G.;
Peng, Tsung-Hung

Project Number:

7868

Organization/s:

Lamont-Doherty Geological Observatory

Project Monitor:

Osterberg, Charles L.
DOE, Ecological Research
Division
301-353-3035

Project Summary

In order to improve a numerical model which accounts for the bomb-produced ^{14}C inventories in the equatorial and temperate Pacific, we are reconstructing the temporal history of ^{14}C and ^{90}Sr in surface waters using the chemistry of annual growth bands in corals. We have successfully sampled large corals (30-120 years old) along a transect from 28°N lat. (Midway) to 22°S lat. (Tongatapu) in the Pacific. This represents 3N. temperate, 4 tropical, 3 transitional, and 3 S. temperate sites.

Carbon-14 data from a Bermuda coral for the period 1950-1973 are compatible with previous measurements for Bermuda and the Florida Keys. The $^{90}\text{Sr}/\text{Sr}$ data from the same Bermuda coral are in agreement with historical measurements of surface water in this region. The ^{90}Sr content in the Bermuda coral peaks in 1965. The $^{90}\text{Sr}/\text{Sr}$ data indicate that post-1965 surface water ^{90}Sr dilution rates decrease possibly because the subsurface water which dilute the surface layer ^{90}Sr from isopycnal outcrops and/or vertical mixing.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$103KDeep Sea Carbonates: Accumulation
Dissolution and Carbon Dioxide Flux

Principal Investigator/s:

Project Number:

Berger, Wolfgang A.

OCE78-25587

Organization/s:

Project Monitor:

Scripps Institution of Oceanography

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

This project involves studies on the chemical processes at the ocean-sediment interface that affect carbonate accumulation rates and impact the atmosphere-ocean carbon dioxide system. The goals of the study are:

- (1) To assess the rates of carbonate dissolution in representative regions of the world ocean;
- (2) To study mixing processes in the uppermost sediment layer, especially the effects of burrowing by organisms, to help clarify the effects of mixing on dissolution and the effects of mixing on signal recording by sediments and on dating of events;
- (3) To determine in detail the events associated with the last drastic climate change, the deglaciation 15,000 to 10,000 years ago, as recorded by deep sea sediments; and
- (4) To determine changes in upwelling as a function of climatic change, and its role as a feedback mechanism through carbonate dissolution and carbon dioxide exchange between the ocean and atmosphere.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$30K

Dissolution Rates of Calcium Carbonates
in Deep Sea, ISWAC III Experiment in
the Pacific

Principal Investigator/s:

Project Number:

Honjo, Susumu

OCE79-01385

Organization/s:

Project Monitor:

Woods Hole Oceanographic Institution

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

Elucidation of the in situ dissolution rates of calcareous material supplied to the abyssal oceans is fundamental to any model attempting to explain the distribution of this material in deep sea sediments. Direct measurement of the dissolution rate of calcium carbon suspended in situ has been attempted in the past on synthetic and biogenic carbonates. While these results have been of great interest concerning the relative dissolution rates in the depth profile, it appears that the absolute rates are approximately one-half to one order of magnitude lower than expected from laboratory dissolution rates of sediment material in combination with estimated in situ undersaturation conditions. This research program will deploy three (3) in-situ water circulators (ISWAC) at 4,000, 5,000, and 6,100 m in the Horizon Passage where a classical experiment was conducted. Forty dissolution sensors will also be suspended along the mooring array between 400 m to 6,100 m from the water surface. The ISWAC instrument packages will be deployed along with sediment trap mooring arrays in another experiment aimed at gaining knowledge of the vertical transport of material.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$70KFluorocarbon Distribution
in the Pacific Ocean

Principal Investigator/s:

Project Number:

Cline, Joel

Organization/s:

Project Monitor:

Pacific Marine Environmental
Laboratory, NOAACline, Joel
NOAA, Pacific Marine
Environmental Laboratory
206-442-4900

Project Summary

Develops techniques for measuring Fluorocarbons 11 and 12 distribution in the ocean and makes the measurements. Analyzes the data to detect the mixing and transport of gases, like CO₂, which are absorbed at the surface. Ultimate goal is to determine better the mixing of CO₂ into the main body of ocean waters.

Category: IA5

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$13K</u>
Historical C-14 Measurements from the Atlantic, Pacific, and Indian Oceans	
Principal Investigator/s:	Project Number:
Fairhall, Arthur W.	7852
Organization/s:	Project Monitor:
University of Washington	Osterberg, Charles L. DOE, Ecological Research Division 301-353-3035

Project Summary

Objective: To evaluate the existing data base relative to questioning the role of the ocean in assimilating fossil carbon.

Approach: To retrieve the ^{14}C and SCO_2 measurements taken by Dr. Fairhall over the past 20 years and format the data into a useable hard copy form, tabulating it by time, geographic location, and depth. Ancillary measurements will include salinity and temperature, which were taken at the same time, although many of these data will have to be obtained from the log books of the various cruises of which the ^{14}C sampling program was a part. The only laboratory observations that need to be finalized are S^{13}C measurements on approximately 200 aliquots of CO_2 in breakseal tubes. These measurements are necessary to correct the raw ^{14}C counting data for fractionation effects.

Category: IA5

Carbon Dioxide Project Report

Project Title: North Atlantic Study of the Transient Tracers in the Ocean Program (NAS/TTO)

Funding: FY 80 · \$1013K DOE NSF \$1013K

Principal Investigator/s:

Keeling, Weiss, Williams (1)
 Broecker, Takahashi (2)
 Ostlund (3)
 Brewer, Jenkins, Armi, Georgi (4)

Project Number:

8167

Organization/s:

Scripps Institution of Oceanography (1)
 Lamont-Doherty Geological Observatory (2)
 University of Miami (3)
 Woods Hole Oceanographic Institution (4)

Project Monitors:

Volchok, Herbert
 DOE, Environmental
 Measurements
 Laboratory
 212-620-3619

Collins, Curt
 NSF, Ocean Sciences
 202-357-7906

Project Summary

The goals of the NAS/TTO program are to: (1) study deep ocean circulation and mixing processes by using chemical tracers, (2) study the flux of anthropogenic carbon dioxide (CO₂) into the ocean through its correlation with a multiplicity of tracers, and (3) to provide a data set to permit testing physically derived concepts of ocean circulation. The proposed program involves shipboard and laboratory measurements of physical and chemical properties of water collected in the northern and western North Atlantic Ocean. The program requires approximately nine months of ship time and approximately 240 soundings of water properties. The primary field program would last for eight months. On station, continuous vertical soundings of temperature, conductivity, pressure, dissolved oxygen and light scattering will be made and discrete water samples collected for the measurements of pCO₂, alkalinity, pH, total CO₂, nutrients, Tritium, Helium-3, Carbon-14, Krypton-85, Radon-222 and Argon-39. Between stations, pCO₂, temperature, conductivity, and nitrous oxide will be measured continuously in surface waters and the carbon dioxide content of the atmosphere will also be continuously measured. The field program will be followed by two years of chemical analyses as well as data analysis and interpretation.

Remarks: Funded jointly by NSF and DOE.

Category: IA5

Carbon Dioxide Project Report

DOE NSF

Project Title:	Funding:	FY 80	\$263K	\$197K
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Preparatory (Spin-up) Work for the North Atlantic Study of the Transient Tracers in the Oceans Program (NAS/TTO)

Principal Investigator/s:

Broecker, Wallace S.
Jenkins, William
Williams, Robert

Project Number:

8577

Organization/s:

Lamont Doherty Geological Observatory
Woods Hole Oceanographic Institution
Scripps Institution of Oceanography

Project Monitors:

Volchok, Herbert
DOE, Environmental
Measurements
Laboratory
202-620-3619

Collins, Curt
NSF, Ocean Sciences
202-357-7906

Project Summary

- 1) Develop a program for measuring Kr-85 in sea water. Krypton-85 measurements in sea water, when used in conjunction with measurements of C-14 and H-3, permit estimates of the transport and mixing rates of fossil fuel CO₂ in the deep ocean.
- 2) Analyze samples obtained in the NAS/TTO. The main objective is to provide the capability to document the passage of H-3 and He-3 from the atmosphere in the oceans and to follow these "tracers" through oceanic mixing and transport processes. The mass spectrometric method for direct He-3 analysis is the only technique available.
- 3) Acquire expendable equipment necessary for the collection and processing of physical and geochemical oceanographic data. During large expeditions such as the NAS/TTO, the equipment will be on board ship, providing the flexibility and speed for complex sample and data acquisition and data management

Remarks: Funded jointly by DOE and NSF.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$110K

The Reactivity of Deep-Sea Sediment with
Respect to Calcium Carbonate Dissolution:
Laboratory Determination of Its Variation

Principal Investigator/s:

Project Number:

Honjo, Susumu; Keir, Robin S.

OCE79-09456

Organization/s:

Project Monitor:

Woods Hole Oceanographic Institution

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

Although the kinetics of calcium carbonate dissolution in sea water has received increasing attention in recent years, virtually no attention has been given to the problem of how the reactivity of natural sediments changes as the degree of dissolution increases. Indirect evidence, as to whether the reactivity of natural sediment assemblages increases or decreases as dissolution becomes more extensive and by what magnitude, from laboratory and field observations, is contradictory and confusing. In order to accurately predict how rapidly sediment will neutralize the fossil fuel CO₂ injected into the deep-sea, it is necessary to know whether or not sediment remains reactive as it becomes partially dissolved. This research proposal is aimed towards gaining that knowledge. By utilizing samples from a core collection and from freshly obtained box cores, the reactivity in various stages of partial dissolution will be determined. The results of these experiments will significantly improve our understanding of the sedimentological factors affecting dissolution in deep-sea sediment.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$60KRetrieving Annual Cycles of Water
Temperature by Coral Thermometry

Principal Investigator/s:

Project Number:

Smith, Stephen V.; Chave, Keith E.

OCE79-03945

Organization/s:

Project Monitor:

University of Hawaii - Manoa

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

It has been established by laboratory experiments and field validation that the Sr/Ca ratio of coral aragonite is a simple function of water temperature and the Sr/Ca ratio of the water in which the coral grows. Preliminary data suggest that a temperature profile through coral heads can be calculated on the basis of the skeletal Sr/Ca variation, and that this temperature record can be used in conjunction with the chronometric record of density bands to estimate long-term ambient water temperature. It is proposed to build on these findings by collecting duplicate coral cores from several locations in the Hawaiian Islands, to slab and x-ray these corals, and to sample the slabs for detailed Sr/Ca transects. Corals will be sampled from other locations, as convenient. Sub-annual temperature cycles over a timespan of decades to centuries will then be calculated and the internal consistency, reliability, and utility of the patterns obtained evaluated.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$28K

Solution Chemistry of Seawater

Principal Investigator/s:

Project Number:

Bates, Roger

OCE79-22029

Organization/s:

Project Monitor:

University of Florida

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

A knowledge of the basic physical chemistry of seawater is fundamental to understanding the chemical reactions and transformations that occur in the ocean. This research will be concerned with the electrolyte chemistry of seawater both on a theoretical and applied basis. A standard reference system for pH measurements will be established for seawater, as a function of temperature and salinity. This system will be similar in nature to the National Bureau of Standards system for dilute electrolyte solutions. Establishment of this reference system for seawater will contribute significantly to resolving problems in the measurement of pH in seawater. Apparent dissociation constants for acids in seawater will be put on a sound thermodynamic basis. Additional studies will be done on the behavior of specific ion electrodes in seawater. These results will be applied to the evaluation of single ion activity coefficients.

Category: IA5

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$37KTechnical Support for Collection
of C-14 Samples During FGGE

Principal Investigator/s:

Project Number:

Williams, Robert

8120

Organization/s:

Project Monitor:

Scripps Institution of Oceanography

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

This involves the technical support required for the collection of large volume (275 liter) water samples, the extraction therefrom of the carbonate for shipment to the University of Washington for analysis of C-14 by Drs. Stuiver and Quay. It also includes the measurement, at sea, of nutrients (O_2 , PO_4 , NO_3 , SiO_3), total carbon and alkalinity. The at-sea operation was performed aboard vessels supporting the NORPAX mid-equatorial experiment during March 1979 (aboard RV Gyre) and during November 1979 (aboard RV Wecoma). These vessels made approximately bi-monthly expeditions between Honolulu and Tahiti and back. Hydrographic data was also available for support of this work.

Category: IA5

I, A, 6

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

A. Research Subcategory: Fluxes of CO₂

6. Research Issue: Oceanic Sediments

1. Significance: If shallow water sediments are now dissolving, they would represent a sink not usually considered in most carbon cycle models. This would mean the ocean is capable of absorbing more CO₂ than previously considered. The deep oceanic sediments will form the ultimate repository for the excess CO₂, but on the time scale of thousands of years.

2. Program Description: The first step is to confirm the reality of shallow water carbonate dissolution (e.g., does it occur). Current studies, both laboratory and field experiments, suggest that it does but that it is not now a large sink. Some further work could determine the extent of the soluble sediments to see if they could become a significant contributor to oceanic carbonates in the near future. Studies of bioturbation of deep sediments and laboratory experiments of dissolution of deep water sediments will be undertaken with lower priority.

3. Priority: Assess the role of shallow and deep water carbonate dissolution.
Medium (shallow water) Low (deep water)

4. Participating and Funding Agencies: NSF, DOE, NOAA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Hold a workshop on carbonate dissolution. Initiate a study of role of ocean biology in carbon transport.	15
1981	Literature review and initial study of shallow water carbonate dissolution.	200
1982	Initiate field study shallow water carbonate dissolution and paper study of deep water carbonate dissolution.	200
1983	Continue study of shallow and deep water carbonate dissolution. Prepare draft summary report.	200
1984	Continue study of shallow and deep water carbonate dissolution. Complete status report on carbonate dissolution and associated processes.	200

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$52K</u>
Biogrochemistry of Calcium Carbonate Sediments	
Principal Investigator/s:	Project Number:
Kriausakul, Nivat; Mitterer, Richard M.	OCE79-25389
Organization/s:	Project Monitor:
University of Texas at Dallas	Anderson, Neil NSF, Ocean Sciences 202-357-7910

Project Summary

This project is an investigation into the influences and effects of natural organic matter on the geochemistry of calcium carbonate. The kinetics of CaCO_3 precipitation and dissolution are modified by the presence of surface-active organic substances. The composition of the organic matter associated with carbonate sediments differs from that associated with non-carbonate sediments. Organic matter relatively enriched in aspartic acid is preferentially associated with carbonate grains while non-carbonate sediments do not exhibit any preference for an aspartic acid phase.

A detailed investigation of the amino acid composition of the adsorbed organic matter by separation and analyses of different molecular weight fractions of organic matter from sediments collected from different environments will be made. The extracts will be further characterized by the degree of adsorption to mineral surfaces and their metal-complexing ability. In addition, the distribution of amino acids between the adsorbed phase and the higher molecular weight dissolved organic matter of interstitial water in sediment cores will be determined. From this, the fate of the amino acid fraction of the organic matter during early diagenesis will be elucidated.

Category: IA6

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$17KCalcium Binding in Molluscan
Shell Matrix

Principal Investigator/s:

Project Number:

Gordon, Julius

Organization/s:

Project Monitor:

University of Delaware

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

The dominant mode of calcium carbonate formation in the marine environment is by organisms. The biochemical processes involved in calcium carbonate formation in bivalves and gastropods are believed to involve calcium binding proteins. Many of these proteins are retained in the calcium carbonate shell after formation and may exert a significant influence on the subsequent behavior of the calcium carbonate in seawater and sediments.

This research involves studies of the calcium binding properties of organic components of shell matrix. Earlier work concluded that insoluble organic matrix compounds were not responsible for either calcium binding or catalyzing calcium carbonate precipitation. This phase of the research will concentrate on the chemical characterization of the soluble protein fraction of the matrix, part of which does have significant calcium binding ability.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$75KCarbonate Dissolution of Biogenic
Particles in the Ocean

Principal Investigator/s:

Project Number:

Feeley, Richard

Organization/s:

Project Monitor:

Pacific Marine Environmental
Laboratory, NOAAFeeley, Richard
NOAA, Pacific Marine
Environmental
Laboratory
206-442-5436

Project Summary

The purpose of this project is to determine the amount of dissolution of carbonates from organically formed particles as they fall through the water columns, thus adding carbonate ion to the water column. Initial studies will be in the Pacific where there is reason to believe this process could be significant. Studies involve collection using sediment traps as well as chemical analytical and subsequent analysis.

Category: IA6

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$71KDetermination of the Solubility of
Calcite and Aragonite in Seawater

Principal Investigator/s:

Project Number:

Morse, John W.

OCE79-19242

Organization/s:

Project Monitor:

University of Miami

Anderson, Neil
NSF, Ocean Sciences
202-357-7910

Project Summary

This project involves studies aimed at understanding the role of surface chemistry in determining the behavior of calcite and aragonite in the marine environment. Primary emphasis will be placed on the chemistry of Mg and Sr in surface overgrowths and adsorption layers. Two different chemo-stat techniques will be used to determine the influence of solution composition, growth rate, and surface history on the composition, solubility, and reactivity of overgrowths. Three different experimental techniques will be used to elucidate the chemistry of the solid-solution interface. In addition to "wet chemical" and radioisotope tracer techniques, the composition of the solid surfaces and overgrowths will be studied by scanning Auger spectroscopy and scanning secondary ion mass spectroscopy.

Category: IA6

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$110KGeological Perspective on
Global CO₂

Principal Investigator/s:

Project Number:

Sundquist, E. T.

Organization/s:

Project Monitor:

U.S. Geological Survey
N.E. Region Research Group,
Water Resources DivisionSundquist, E. T.
USGS, Reston, VA
703-860-6083

Project Summary

Using numerous methods available through USGS scientists, this project investigates the possibility of past variations in the world's (natural) CO₂ balance, as well as the interrelationships between any such variations and global climate. Hypotheses are suggested and tested using geologic information which is incorporated into a computer model of the global carbon cycle. In addition to this "retrodictive" modeling, the project conducts research in aspects of marine carbonate geochemistry and organic geochemistry which are particularly pertinent to the long-term effects of anthropogenic CO₂. This project also provides a technical framework for coordination of USGS CO₂ related research, including coordination with research in other agencies.

Remarks: Also applies to ICI, IDI, IIIA4.

Category: IA6

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 · \$13K

Strategies of Estimation of Global CO₂
Uptake in the Ocean Mixed Layer Owing
to Reactions of CO₂ with Solids

Principal Investigator/s:

Project Number:

Garrels, Robert M.; Mackenzie, Fred T.

8347

Organization/s:

Project Monitor:

Northwestern University

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

A workshop was held of approximately 18 scientists to consider the best strategies for estimating global uptake of carbon dioxide in shallow ocean waters as a result of reactions of CO₂ with solid materials. The meeting lasted 2 1/2 days, was situated in the U.S., and was held on March 20 -22, 1980. Both domestic and foreign scientists were involved.

66

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

B. Research Subcategory: Atmospheric Storage

1. Research Issue: Observations of Atmospheric CO₂

1. Significance: Continued measurements of the increases in atmospheric CO₂ are necessary to monitor its growth, to validate models of the carbon cycle, and for other applications.

2. Program Description: Expansion of the current world-wide, international observing network (11 stations) to about 25 stations is being carried out. Most new sites are operational; a few are still being negotiated. This expanded network will provide nearly global coverage. Improved instrumentation using gas chromatography is being evaluated and will be employed if feasible.

3. Priority: The world-wide network for measuring atmospheric CO₂ has been expanded. NOAA is the main U.S. agency involved. The integrity of the long-term record must be maintained. Maintenance of standard gases available for use in measurements must continue. High

The atmospheric CO₂ data should be interpreted to assist in modeling the carbon cycle. High

4. Participating and Funding Agencies: NOAA, NSF, DOE

5. Milestones and Budget

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Expand global measuring network completed. Test of gas chromatography technique.	100
1981	Determine feasibility of gas chromatography completed. Begin procurement and installation of instruments if practicable. Continue measurements and analyses.	350
1982	Install chromatographic instruments; overlap with IR instrumentation.	350
1983	Continue measurements and analyses. Continue comparison between chromatographic and IR sensors in field locations. Prepare draft summary report.	350
1984	Continue measurements. Assess atmospheric network and its results. Complete summary of findings of atmospheric storage problem.	350

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$94KGas Chromatograph Measurements
of Atmospheric CO₂

Principal Investigator/s:

Project Number:

Weiss, R.

Organization/s:

Project Monitor:

Scripps Institution of Oceanography

Machta, Lester
NOAA, Air Resources
Laboratory
301-427-7609

Project Summary

Development and construction of two gas chromatographs to monitor atmospheric CO₂. This device could reduce greatly the requirement for reference gases at GMCC monitoring stations and so improve the efficiency of monitoring.

Category: IB1

Carbon Dioxide Project Report

Project Title:	Funding: <u>FY 80</u> <u>\$100K</u>
Miniaturized Rapid-Response for Atmospheric Concentration of Carbon Dioxide	
Principal Investigator/s:	Project Number:
Bingham, G.	3032
Organization/s:	Project Monitor:
Lawrence Livermore National Laboratory	Goldstein, Gerald DOE, Pollutant Characterization and Safety Research Division 301-353-5348

Project Summary

We have completed the construction and field testing of the prototype miniature, battery-powered, nondispersive, infrared, carbon dioxide sensor begun with NSF funding and continued by the DOE-CO₂ Program in FY 1979. Designed as a test bed to prove the basic principles of a sensor employing a corrected miniature, open-sided, folded-optical-path absorption cell, the prototype meets many of the original design goals set for the CO₂ sensor. Based on the experience gained with the prototype sensor, we will develop three second generation prototype sensors optimized for the three environmental sensing tasks for which currently available CO₂ sensors are not adequate: making CO₂ measurements inside small chambers for plants and animals, tower-based, eddy-flux measurements, and aircraft-based, eddy-flux measurements. Technical reports on sensor design criteria will be prepared and published. Measurement techniques using the new sensors will also be validated and published.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$840KObservations and Analysis of
Atmospheric CO₂

Principal Investigator/s:

Project Number:

Hanson, Kirby

Organization/s:

Project Monitor:

Global Monitorial for Climatic Change,
Air Resources Laboratory, NOAAHanson, Kirby
NOAA/GMCC/ARL
303-497-1000 ext. 6361

Project Summary

Maintenance of a world-wide network of stations to monitor atmospheric concentration of CO₂. The network consists of four stations monitoring many other quantities and a special flask-sampling network of about 15 stations for CO₂ only. Continued improvements in instrumentation, calibration procedures and sampling design are part of this effort.

Data are analyzed to monitor trends in global concentration and seasonal variations and to relate these to variations in other quantities such as sea surface temperature and global circulation to detect regional sources and sinks as well as improve global carbon cycle models.

Category: IB1

Note: For additional research supporting this issue refer to:

Title

Category

A Study of the Abundance of
Carbon Dioxide in the Atmosphere
and Its Exchange with the Ocean

IA4

72

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

C. Research Subcategory: Past Records of CO₂

1. Research Issue: Past Records of CO₂

1. Significance: Knowledge of the atmospheric concentration prior to the systematic measurements begun in 1958 would greatly help the development and validation of carbon cycle models. The CO₂ concentration in past ages could, in conjunction with past climate indicators, help suggest future CO₂-climate relationships.

2. Program Description: Several possibilities for establishing atmospheric CO₂ concentrations will be investigated. Spectroscopic observation of the sun could provide estimates from 1920-1950; ice cores from glaciers and tree ring ¹³C/¹²C and ¹⁸O/¹⁶O ratios may provide information if some of the current questions about the techniques can be resolved. Other geological records and techniques will be examined to determine if past CO₂ concentrations on geological time scales can be estimated. When past CO₂ concentrations are found, they will be compared with simultaneous estimates of climate.

3. Priority: Determination of past (pre-1958) CO₂ concentrations on both historic (past 5,000 years) and geologic (>3,000 years BP) time scales. High (historic) Low (geologic)

4. Participating and Funding Agencies: USGS, NSF, DOE

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Examine Smithsonian and other solar spectra for CO ₂ concentration information. Examine CO ₂ of ice cores. Hold workshop on geological CO ₂ concentrations. Further work on oceanic techniques to reconstruct past CO ₂ levels.	280
1981	Continue examination of spectra and geological records for CO ₂ changes.	350
1982	Continue data analyses and interpretation of past concentration and evaluate accuracies of estimates.	350

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1983	Reassess value of accepted and promising new techniques to estimate past CO ₂ levels. Prepare draft summary report.	350
1984	Complete report on past CO ₂ levels. Complete studies needed for final report.	350

Carbon Dioxide Project Report

Project Title:

Carbon Cycle Project

Funding: FY 80 \$50K

Principal Investigator/s:

Arthur, M.

Project Number:

Organization/s:

U.S. Geological Survey
Branch of Regional Geochemistry
and Geophysics
Geologic Division

Project Monitor:

Arthur, M.
USGS, Denver, CO
303-234-4026

Project Summary

This project involves detailed stratigraphic sampling of Jurassic through Tertiary fine-grained deep sea limestones. Analytical work performed to date on samples from Mexico, the United States, England, the North Sea, Netherlands, France, Italy, and the North Atlantic shows that carbon isotope data on whole-rock chalk or pelagic limestone samples can be correlated with considerable confidence over distances of at least thousands of kilometers. These isotopic cycles appear to reflect changes in oceanic circulation patterns which, in turn, may be related to global sea level changes, temperature fluctuations, variations in the amount of organic carbon which was buried in marine sediments, and variations in atmospheric CO₂.

Category: ICI

Carbon Dioxide Project Report

Project Title: Funding: FY 80 \$73K

Atmospheric ^{14}C Activity and Its Relationship
to Solar Variability and Climatic Change

Principal Investigator/s:

Stuiver, Minze

Project Number:

ATM78-21608

Organization/s:

University of Washington

Project Monitor:

Hecht, Alan
NSF, Atmospheric
Sciences,
202-357-9892

Project Summary

Past concentrations of ^{14}C in the atmosphere are being measured from annual growth rings in well dated trees. After proper calibration of the ^{14}C record for the past two or three centuries where solar variability is known from historical records, these ^{14}C data can be used to derive past solar variability.

Once the paleo-solar record is established, it can be compared with past climatic changes in order to assess the influence of solar fluctuations on climate.

The atmospheric ^{14}C record, when combined with carbon reservoir modeling, also results in improved estimates of the rate of oceanic uptake of $^{14}\text{CO}_2$. The information derived is important in assessing the oceanic uptake of excess CO_2 produced by fossil fuel combustion.

Carbon Dioxide Project Report

Project Title: Funding: FY 80 \$242K

Atmospheric CO₂ Abundance--An Archival
Study of Spectroscopic Data

Principal Investigator/s:

Project Number:

Stokes, G. M.; Stokes, R. A.

3064

Organization/s:

Project Monitor:

Pacific Northwest Laboratory

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

Purpose: The purpose of the proposed research is to determine a pre-industrial value of the atmospheric carbon dioxide abundance that is of sufficient quality to serve as a test of global models of the carbon cycle.

Technical Approach: The proposed determination of a pre-industrial CO₂ abundance will be based on a hitherto unexploited source of data, the measurements of the near-infrared solar spectrum that have been accumulated since the mid-1890s for astronomical purposes. Since a spectroscopic program of this kind has not been previously attempted, a special approach to the problem is required, which entails two related projects. The first is an analysis of new spectroscopic data to be accumulated with the Fourier Transform Spectrometer (FTS) of the Kitt Peak National Observatory (KPNO). This analysis will enable a detailed identification of possible sources of systematic error that may arise in the study of data which were not specifically collected for the determination of telluric abundances. The second is the identification and evaluation of archival solar spectra that may be suitable for this study and their analysis. In general, this analysis will proceed in a reverse historical order, working back toward the spectra of S. P. Langley accumulated in the 1890s.

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$34K</u>
Dendrochronology of Bristlecone Pine	
Principal Investigator/s:	Project Number:
Ferguson, C. W.	EAR78-04436
Organization/s:	Project Monitor:
University of Arizona	Lance, John NSF, Earth Sciences 202-357-7915

Project Summary

This project involves research on the bristlecone pine chronology. Work will continue on strengthening and extending the known continuous range, which now extends to more than 8,000 years before present. Further studies will be aimed at connecting older fragmentary sequences which offer a possibility of extension to 10,000 years.

The bristlecone chronology has been useful in dating a number of events of interest in geology, archaeology, and paleoclimatology. Calibrations of fluctuations in the carbon isotope composition of the atmosphere have been of particular importance. The project will include collection and calibration of samples for a number of other laboratories and continued studies on cyclic variations in tree-ring growth.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$141KGeochemical Determination of Biospheric
CO₂ Fluxes to the Atmosphere

Principal Investigator/s:

Project Number:

Stuiver, Minze

8113

Organization/s:

Project Monitor:

University of Washington

Beadle, Robert W.
DOE, Pollutant Charac-
terization and Safety
Research Division
301-353-3764

Project Summary

Atmospheric CO₂ levels can be increased both by CO₂ derived from fossil fuel combustion and by CO₂ derived from land clearing and related changes in the carbon biomass. To understand the partitioning of excess anthropogenic CO₂ between the atmosphere, oceans, and biosphere, a better knowledge of the size of the sources is needed. Release of anthropogenic CO₂ causes changes in the ¹³C and ¹⁴C isotope content of atmospheric CO₂. These changes are presented in tree ring sequences. Changes are also caused by other variables such as temperature and recycling of locally produced biospheric CO₂. The proposed work involves the determination of the anthropogenic ¹³C and ¹⁴C record after an evaluation of the changes induced by other variables. The ultimate purpose is the determination of past net biospheric CO₂ fluxes to the atmosphere.

Category: IC1

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$44K

Reconstruction of the History of the
Atmospheric CO₂ Content and ¹³C/¹²C
Ratio by Ice Core Analysis

Principal Investigator/s:

Project Number:

Oeschger, H.; Stauffer, B.

8183

Organization/s:

Project Monitor:

University of Bern

Volchok, Herbert
DOE, Environmental
Measurements
Laboratory
212-620-3619

Project Summary

Measurements of the CO₂ content of old natural ice and firn samples are probably the only possibility to reconstruct the CO₂ content of ancient atmospheres. However, the CO₂/N₂ ratio measured in ice samples is not identical to that of the ancient atmosphere. In the cold central parts of the big ice sheets, ice is formed by sintering of dry snow and firn. After close-off, the CO₂ content in the air bubbles is--at least at the beginning--identical with the atmosphere one, but there is also CO₂ in the ice lattice, either dissolved or in another chemical form. During the long times involved, the CO₂ in the bubbles and the CO₂ in the ice may to a certain degree exchange.

Previous measurements show that by an extraction in two steps it should be possible to distinguish between the CO₂ in the bubbles and the CO₂ in the ice. To correct for a possible exchange between the two CO₂ reservoirs, statistical methods seem most promising. Therefore, it is necessary to analyze many samples. ¹³C/¹²C measurements on the extracted CO₂ could help to get information on changes in the relative sizes of the CO₂ reservoirs, atmospheres, biosphere, and ocean.

Category: ICI

Note: For additional research supporting this issue refer to:

Title

Category

Geological Perspectives on Global CO₂

IA6

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I, D, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

I. CO₂ Research Category: The Carbon Cycle

D. Research Subcategory: Models of the Carbon Cycle

1. Research Issue: Models of the Carbon Cycle

1. Significance: The final goal of the carbon cycle research program is to produce a tool for forecasting future concentrations of atmospheric CO₂. A credible numerical carbon cycle will be built upon all of the information on the carbon reservoirs and transfers. The prediction will employ various scenarios of fossil fuel usage and other significant perturbations caused by man's activities.

2. Program Description: A workshop in the spring of 1979 identified program elements causing uncertainties in the carbon cycle. Several independent groups will develop and test numerical models of the carbon cycle. Frequent intercomparisons will be held but a major international workshop on modeling will take place in FY 1983 to reassess the needs for model improvement.

3. Priority: Development, testing and use of carbon cycle models based on new findings arising from other parts of the DOE (and other) research programs.
High

4. Participating and Funding Agencies: NSF, DOE, NOAA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Contract several model development efforts with scientists or organizations that have diverse interests (e.g., oceanography, biology).	300
1981	Continue to develop models. Test their output against validation data. Evaluate priorities in carbon cycle research.	400
1982	Continue model development. Engage in a national and international model comparison.	400
1983	Contract new scientists and/or organizations to develop second generation carbon models. Prepare draft summary report.	750
1984	Complete a summary position on carbon cycle models. Exercise newest models with latest energy use scenarios.	750

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$51KModeling Mixing of Transient
Tracers in the Ocean

Principal Investigator/s:

Project Number:

Sarmiento, J.

Organization/s:

Project Monitor:

Princeton University

Elliott, William P.
NOAA, Air Resources
Laboratory
301-427-7645

Project Summary

Observations of the distribution of transient tracers in the ocean (see North Atlantic Study of the Transient Tracers in the Ocean Program (NAS/TTO), Category IA5) will be modeled in general circulation model of the ocean. (The model is a Geophysical Fluid Dynamics Laboratory product.) The purpose is to model the mixing of fossil-fuel penetration into the main body of the ocean after it has penetrated the surface.

Also included in this task is a small effort to investigate, by oceanic models, the flow of water under the Ross Ice Shelf to help determine whether it is growing or receding.

Category: ID1

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$8K .

The Role of the Tropical Forest on
the Carbon Cycle of the World

Principal Investigator/s:

Project Number:

Lugo, Ariel; Hall, Charles; Brown, Sandra;
Holdridge, Leslie; Tosi, Joseph

3698

Organization/s:

Project Monitor:

Institute of Tropical Forestry, Puerto Rico
Tropical Science Center, Costa Rica
Cornell University

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

The objectives of this study are:

- 1) To survey and compile the available literature and unpublished reports dealing with carbon storage and carbon flow in tropical ecosystems.
- 2) To categorize the data by Life Zone and by stages of succession.
- 3) To assemble available evidence on the impact of human activities on the carbon flow of different Life Zones.
- 4) To simulate these data with an existing ecosystem model in order to extrapolate trends in the available data and to elucidate the significance of particular transfer mechanisms and feedbacks.
- 5) To make recommendations for priority research needs relative to the role of tropical ecosystems in exchange of carbon with the earth's atmosphere.

To accomplish these objectives each institution receives a subcontract. Scientists work independently on the objectives given above communicating periodically by phone, letter, and in meetings. Bibliographic work is done independently and stored in Cornell. Data summaries are sent periodically to modelers as group inputs to the model. Results are discussed in meetings where group consensus develops for specific issues. Reports develop out of symposiatype meetings where each scientist presents the product of individual or group work.

Category: ID1

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$170KThe World Carbon Budget: An Analysis
Through Modeling

Principal Investigator/s:

Project Number:

Woodwell, George M.; Hobbie, John E.;
Peterson, Bruce J.; Botkin, Daniel R.;
McIlillo, Jerry M.

DEB78-05327

Organization/s:

Project Monitor:

Lance, John
NSF, Earth Sciences
202-357-7915

Project Summary

This research will examine the potential importance of man-biota-CO₂ interactions by an approach through detailed modeling. The modeling will emphasize the biotic aspects because these are the topics that seem to be crucial to understanding the fate of carbon. The study will deal with two questions: To what extent is the biota likely to be a source or sink for atmospheric CO₂ and how important are transfers of particulate organic carbon into the oceanic depths in serving as a sink for atmospheric carbon. The approach will include experimentation with a number of plausible biological models to indicate the range of possible biologic effects. Models will be developed at several levels of complexity and will utilize data from the literature and information from major research groups.

Category: ID1

Note: For additional research supporting this issue refer to:

<u>Title</u>	<u>Category</u>
Global CO ₂ Source/Sink Budget and Climatic Effects	IIA1
Geological Perspectives on Global CO ₂	IA6

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II. RESEARCH ISSUES IN CLIMATE EFFECTS

A. Climate Models of CO₂ Effects

1. Development and Modification
2. Verification Studies
3. Sensitivity Studies
4. CO₂ Perturbation Studies

B. Reconstruction of Past Climates

1. Paleo-Climates
2. Historical Climates

C. Climate Scenario Development

D. Evidence of Climate Change

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II, A, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate EffectsA. Research Subcategory: Climate Models of CO₂ Effects

1. Research Issue: Model Improvement and Modification

1. Significance: Numerical models will have to be the primary tools used to make climatic projections. To generate confidence, models must represent all of the relevant aspects of the chemistry and physics of the atmosphere, hydrosphere, cryosphere, and biosphere, and be verified against a wide variety of past climate change scenarios. Because the models depend on the extent of our understanding of the many processes that are involved--particularly of the numerous complex and subtle feedback mechanisms--there is great need for fundamental improvements in our perception of how the climate system functions. Especially because the projected climate changes are unprecedented in mankind's documented climatic experience (i.e., in at least the last 100,000 years), there is a possibility that we are overlooking important mechanisms or improperly representing processes as climate conditions evolve beyond the range of validity of various parameterizations.

The problems of most immediate concern with present projections are the many simplifications made in most of the numerical models being used to project future climate. Present models, for example, are only beginning to treat realistic topography, land-sea distributions and seasonal variations, and still treat only poorly land surface and cryospheric processes, ocean heat capacity and transport, and clouds. Many of these problems can be corrected or, at least, their climatic effects can be much better represented. Although it is not likely that we will have completely satisfactory climate system parameterizations during the next five years due to a combination of limitations including computer capacity, diagnostic capabilities, and lack of a fundamental understanding of many of the components of the climate system, there should be a sufficiently adequate representation of the system to allow reasonable limits to be placed on the effects of increasing carbon dioxide.

2. Program Description: Because of the large number of processes that make up the climate system, a wide range of analytic and numerical models have been developed to represent it. This breadth of approach, ranging from relatively simple one-dimensional models to comprehensive three-dimensional ocean-atmosphere models, offers some assurance that the full range of important response mechanisms are at least being considered since in each model efforts are made to incorporate many of the processes having the temporal and spatial response characteristics appropriate to the issue at hand. The temporal and spatial aspects of the CO₂ problem, however, do require treatment of more mechanisms than are normally required in just representing the present climate.

Model development, improvement, modification, and testing is a continuous and on-going process among the many groups developing numerical models. To accelerate an improved treatment of the potential climatic effects of increasing

CO₂ concentrations, however, requires improvement and testing of particular aspects of these models that may now be of critical importance in studying non-CO₂ issues. A spectrum of simple and complex models will continue to be needed to gain overall insight because of the great range of processes involved. Increased emphasis will be placed on use of GCMs to investigate regional efforts and on improving particular parameterizations in SDMs so that results from the two types of models can be better intercompared. In addition, some new models may be needed that focus on particularly important processes (e.g., oceanic downwelling, polar climate).

Although the direct radiative effects of CO₂ induce a relatively rapid (days) atmospheric response, the indirectly induced climatic effects on the oceans, ice, and land surfaces have a much longer time constant (up to hundreds of years). Since changes in these conditions in turn can further affect the climate, climate models for CO₂ studies must properly treat a very wide range of processes. The major improvements needed in models are now generally recognized to involve treatment of the oceans, cryosphere, clouds, radiation, boundary layer physics, and the land surface and biota. One of the priorities of this program will be to determine which of these areas are most important to placing limits on the climatic effects of enhanced CO₂, and then encouraging improvements of those areas.

Oceans: Oceans strongly affect the atmospheric climate by transporting heat poleward, storing heat as the seasons change, and acting as local sources or sinks of water vapor and heat. Many of the present models, however, treat oceans very simply; for example, as being at constant temperature or as having zero heat capacity. Since land-ocean temperature differences play an important role in determining actual weather patterns, which in turn generate the wind stresses that help drive the ocean currents, improved treatment of the oceans is of very high priority both for climate and effects studies. While it may well be several years before a sophisticated ocean model including ocean currents and heat transport can be properly coupled to an atmospheric model, it is possible that simpler approaches will yield significantly improved climate predictions.

Cryosphere: Global snow and ice play many important roles in influencing the climate. Their high albedo reflects solar radiation that otherwise would warm the earth, thereby allowing further growth in ice extent (the so-called ice-albedo feedback). Sea ice limits evaporation and release of heat from ocean areas and thermally protects large amounts of glacial ice grounded below sea level. Land ice stores water that would otherwise inundate coastal lands. Of the five regimes of ice and snow (permafrost, glacier, ice sheets, sea ice, and seasonal snow), most attention should be paid to improving the treatment of sea ice and the seasonal snow cover so that existing models can be better verified and future effects better estimated.

Clouds: Clouds reflect back to space about 15-25% of the incoming solar radiation (thereby tending to cool the surface), but they also tend to restrict the earth's emission of infrared radiation (thereby tending to warm the surface by a similar amount). In addition, of course, clouds are involved in the hydrologic cycle in the atmosphere, although changes in cloudiness are not easily related to changes in precipitation. If global cloudiness should change (either cloud amount, height or latitudinal distribution) in response to CO₂-induced

warming and circulation changes, an important feedback mechanism could exist that is now handled in models only crudely, in large part because of a lack of fundamental understanding. Although some recent work suggests that cloud feedback may not be as important as previously thought on a global basis, more thorough analysis of surface and satellite data on cloud type, amount, and height and more satisfactory treatment of clouds in models is needed to assess latitudinal, seasonal, and regional effects, particularly in polar areas. Model studies using various approaches to representation of clouds may also be useful in placing limits on the role of this feedback mechanism.

Radiation: Radiative processes are the primary influences controlling global temperatures. Although the radiative properties of carbon dioxide are reasonably well known, there remains some possible problems with the radiative properties of a mixture of gases with overlapping absorption bands. Water vapor is the prime example of a gas with such overlapping absorption spectra. The "e-type" absorption by water vapor, in particular, will become of increasing importance as temperature and water vapor concentrations rise. Measurements of atmospheric infrared fluxes show enhanced emission that has been attributed to a water dimer. Other gases, particularly man-introduced gases such as the fluorocarbons, also absorb strongly in the infrared and contribute to "greenhouse" warming. A second aspect is the possible saturation of CO₂ lines and bands when the CO₂ reaches high enough concentrations.

Atmospheric Concentrations: As energy use increases and the climate warms, other gases may also become of more importance in the radiation calculations than at present. Carbon monoxide, nitric oxide, and methane--some of which are emitted along with the CO₂ emissions as carbon fuels are combusted--can alter atmospheric chemistry and thereby influence the radiative balance. Atmospheric aerosols, both liquid and solid, are also influenced by man's activities, and projections of future conditions may indicate increased importance of such materials in determining atmospheric temperatures. The altered temperatures could further alter the atmosphere's composition (e.g., stratospheric ozone will increase as stratospheric temperatures cool). The different radiative spectral pattern could in turn affect other parameters (e.g., albedo).

Boundary Layer Physics: The parameterizations of clouds and of the boundary layer form a coupled problem. Stratus clouds are formed in the boundary layer. Cumulus clouds are forced by heat and water vapor transport through the boundary layer. More realistic parameterizations of this couple system have taken 5 to 10 years to develop and are just now being tested in GCMs. The success of these parameterizations could greatly improve our ability to simulate climate change.

Land Surface and Biota: Although the ocean largely controls the global atmospheric response, it is on the land and through the biota where the influences of climate change will be felt. The accuracy of model simulations of regional climate changes will be determined largely by the fidelity with which the models translate the atmospheric changes into changes in surface conditions, a translation process involving important, but poorly understood, feedback mechanisms. To improve the climate simulations, models will have to better represent evaporation processes, runoff, albedo, roughness, soil temperature and moisture, frost, and the biota's role in influencing these factors.

3. Priority: Improved treatment of the oceans, cryosphere, and clouds. Very High

Improved treatment of radiation, composition, boundary layer physics, and the land surface. High

4. Participating and Funding Agencies: NOAA, NSF, DOE, NASA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Initial construction of coupled ocean-atmosphere circulation models and seasonally varying simplified models.	750
1981	Improve treatment of cryosphere in climate models; intercompare cloud parameterizations; continue work on treatment of oceans.	1,500
1982	Continue improvement in treatment of radiation, composition, boundary layer, land surface, and ocean prescriptions.	1,700
1983	Continue improvements. Prepare draft summary report.	1,700
1984	Continue improvements.	1,900

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$30K

A Coupled Carbon Dioxide and Water
Vapor Transport Radiation Model

Principal Investigator/s:

Project Number:

Kuhn, William R.

8360

Organization/s:

Project Monitor:

University of Michigan

Gross, Thomas J.
DOE, Carbon Dioxide and
Climate Division
301-353-5586

Project Summary

The intent of our research is to determine the importance of changes in water vapor and the associated clouds on temperature due to variations in carbon dioxide amount. Although there has been much research on the impact of climate from carbon dioxide and water vapor, to our knowledge these constituents have not been coupled in a detailed radiation model. Yet carbon dioxide exerts a significant greenhouse effect which changes temperature, and thus evaporative flux, atmospheric water vapor, and clouds, which themselves strongly influence temperature. These feedback mechanisms may be very important since mean temperature changes of only a few degrees are thought to have important climatic significance.

From a postulated carbon dioxide concentration, a radiation model will be used to generate surface and air temperatures. The computed surface temperature will be used to determine the evaporative flux, and a water vapor transport model will provide modified water vapor concentrations as well as cloud levels, thicknesses, and coverage. A new temperature profile will be calculated and the procedure repeated until a self-consistent water vapor transport-carbon dioxide solution is reached. Sensitivity studies will be performed to ascertain the validity of previous results that do not couple carbon dioxide and water vapor, or require detailed radiation calculations.

Remarks: Also applies to IIA2, 3, and 4.

Category: IIA1

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$98K

Enhanced Research Program on the
Long-Range Climatic Effects of
Increasing Atmospheric CO₂

Principal Investigator/s:

Project Number:

Washington, Warren M.

8119

Organization/s:

Project Monitor:

National Center for Atmospheric
Research

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

The objective of this project is to improve the NCAR circulation model (GCM) and eventually to couple the model atmosphere to an ocean circulation model (AO GCM) in order to: (1) build confidence that the models respond to the addition of CO₂ in the same way as would the real system, (2) describe adequately the changes in the large-scale circulation patterns that will result in more significant regional and seasonal changes of both temperature and precipitation, and (3) determine how ocean circulations and temperatures of the oceanic upper mixed layers will be modified if there is a change in atmospheric temperature and circulation over a period of a few decades.

Well-focused studies will be conducted by devoting an incremental effort devoted specifically to the carbon dioxide problem to take advantage of the GCM and AO GCM ongoing programs.

Remarks: Also applies to IIA2, 3, and 4.

Category: IIA1

Carbon Dioxide Project Report

Project Title:	Funding: <u>FY 80</u> <u>\$100K</u>
Global CO ₂ Source/Sink Budget and Climatic Effects	
Principal Investigator/s:	Project Number:
Hansen, James	146-10-02
Organization/s:	Project Monitor:
NASA Goddard Institute for Space Studies (GISS)	Schiffer, Robert A. NASA, Environmental Observation Division 202-755-8596

Project Summary

This research has two broad objectives: (1) to improve knowledge of the global distribution and magnitude of sources and sinks of atmospheric CO₂, (2) to improve capability to understand the global climatic consequences of increasing atmospheric CO₂.

The studies of sources and sinks of CO₂ will be made with a global atmospheric transport model. After numerical tests and studies of known tracer distributions have been used to check the transport model, the model will be used to study the global distribution and seasonal variation of atmospheric CO₂. By varying the assumed sources and sinks of CO₂ and comparing the atmospheric distributions of CO₂ in the model (particularly the amplitude, phase and shape of the CO₂ seasonal variations) with observations at different locations, it should be possible to improve our quantitative understanding of the sources and sinks of CO₂.

Studies of the climatic effects of increasing atmospheric CO₂ amounts will be made with a range of climate models which have been developed for other applications. Special effort will be made to analyze results obtained with a 3-D general circulation model including diurnally and seasonally varying radiation, computed clouds, realistic distributions of land and ocean and the heat capacity of the mixed layer of the ocean. By obtaining an understanding of the reasons for differences in the results of various models, by testing the models against observations to the extent possible, and by performing sensitivity studies to provide an indication of the range uncertainty in the CO₂ climate effects for those mechanisms included in the models, it will be possible to improve our knowledge of the confidence level which should be attached to projections of possible climatic effects of CO₂.

Remarks: Also applies to ID1 and IIA2, 3, and 4.

Category: IIA1

Note: For additional research supporting this issue refer to:

Title

Category

Carbon Dioxide Effects Research

IIA3

Research on Dynamics of the Climate

IIA4

II, A, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate EffectsA. Research Subcategory: Climate Models of CO₂ Effects.

2. Research Issue: Model Verification

1. Significance: Once models are constructed, it is essential that their results be compared to the observed climate. While this may seem an obvious and straightforward step in evaluating the uncertainty of models, it is actually a very complex process. Comprehensive ocean-atmosphere general circulation models attempt to be nearly as complex as the real system. Comparison with data then becomes extremely difficult and isolation of the causes of differences between model results and the real world is very time-consuming. Verification of the behavior of individual processes provides some simplification, but theoretical limitations and limited model resolution seriously complicate intercomparison of models with the real world. Increasing the coordination of GCM verification, however, with that for simpler models may offer opportunities for fuller testing of parameterization and the role of particular processes in determining the model climate.

Progress over the last twenty years has been slow but steady. Prospects for the next decade appear somewhat more hopeful, however, due to increased computer capacity, improved analysis techniques, expanded model domains, the increased availability of past climatic data, and the vast increase in present data made possible with new satellite capabilities.

2. Program Description: Past verification studies have often considered only annual average or equilibrium seasonal conditions that do not test the model's responsiveness to changing conditions. Major improvement in our confidence in models and in our understanding of their deficiencies can be expected to follow from a rigorous verification of model simulation of:

- a) the annual cycle of the seasons,
- b) the relative frequency and seasonal variation of different weather patterns,
- c) interannual fluctuations,
- d) climatic variations during the last hundred years, and
- e) a variety of glacial and interglacial climates and climatic changes.

Modeling of the last type of climate regime may also offer the opportunity to identify key sorts of paleoclimatic information that may help in identification of mechanisms that cause climatic changes. Increased effort can also be expected on comparing model results for particular continental regions with extended histories for those areas.

Improvements in treatment of processes such as air-sea interaction and annual snow cover will allow more realistic model responses for the various verification periods, so that the focus can move from verification of mean quantities to comparison of moments and variations. Diagnostic techniques being developed for simple models will be extended to the more complex models (and vice-versa).

Highest priority in the verification of model results should focus on those aspects of the model simulations that are believed to amplify the direct radiative effects caused by increased CO₂. These include, particularly:

- a) water vapor feedback (including the seasonal variation of relative humidity, cloudiness, lapse rate, etc.),
- b) ocean surface temperatures,
- c) snow/ice albedo feedback (including land and ocean snow and ice covers), and
- d) surface processes controlling albedo, evaporation, etc.

In addition, attention should be paid to analysis of the capability of models to predict characteristics and frequency of weather patterns.

3. Priority: Verification against seasonal cycle. Very High

Verification against past climate variations, changes, and conditions.
High

4. Participating and Funding Agencies: NOAA, NSF, DOE, NASA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Continued verification studies against equilibrium climatic conditions (e.g., fixed sea surface temperature, etc.).	750
1981-82	Verification of model representation of seasonal cycle, including verification of coupled ocean-atmosphere models.	1,500
1983	Prepare draft summary report.	1,700
1984	Continued verification studies.	1,900

Note: For additional research supporting this issue refer to:

<u>Title</u>	<u>Category</u>
A Coupled Carbon Dioxide and Water Vapor Transport Radiation Model	IIA1
Enhanced Research Program on the Long-Range Climatic Effects of Increasing Atmospheric CO ₂	IIA1
Global CO ₂ Source/Sink Budget and Climatic Effects	IIA1
Carbon Dioxide Effects Research	IIA3
Research on Dynamics of the Climate	IIA4

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate EffectsA. Research Subcategory: Climate Models of CO₂ Effects

3. Research Issue: Sensitivity Studies

1. Significance: Sensitivity studies are a second important aspect of the testing process required to determine the validity of numerical models. It is such studies that help us to understand what mechanisms control and influence the climatic response to perturbations. Because no model can include all of the relevant mechanisms, sensitivity studies can be used to determine which feedbacks are important and which can be largely ignored. Common sensitivity studies (e.g., variation of the solar constant) using different numerical models and different types of models can help clarify differences in results between models. Once such comparisons are understood, the various models can be used to study the many different problems in a coordinated way.

Such testing should permit analyses that will take into account the role of possible biospheric feedback mechanisms (e.g., changes in vegetation patterns), changes in solar input related to sunspots or volcanic eruptions, climatic effects of ocean current changes that we may not be able to predict directly, and so forth. These studies will also allow partial model verification against a number of specific, often short-term phenomena; as for example, especially cold years believed to have followed major volcanic eruptions.

2. Program Description: A wide range of such studies is possible. Each can play a role in helping understand how particular aspects of the models are working. The most common and most important studies will involve:

- a) variation of the solar constant;
- b) variations in cloud amount, height, albedo, and latitudinal distribution;
- c) ice-albedo feedback (including both sea ice and land snow and ice variations);
- d) sea surface temperature change;
- e) land albedo and soil moisture changes;
- f) ocean circulation characteristics; and
- g) stratospheric aerosol loading.

For some of these studies there is evidence from past climate studies indicating the possible range of the expected response. Other studies will provide an indication of the time constants or spatial extent of the possible changes.

Still others will provide information on where evidence of change will first occur. And all will help in understanding how the differences in results from different models can be reconciled.

3. Priority: High

4. Participating and Funding Agencies: NOAA, NSF, DOE, NASA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Initiation of studies to understand the role of the parameterization of the ocean in influencing climatic sensitivity.	750
1981-83	Further investigations of model sensitivity to variations in solar input, land surface processes, snow and ice cover, and ocean circulation. Prepare draft summary report.	1,500 1,700

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$385K

Carbon Dioxide Effects Research

Principal Investigator/s:

Project Number:

Knox, Joseph B.; MacCracken, Michael C.

3028

Organization/s:

Project Monitor:

Lawrence Livermore National Laboratory

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

There are three tasks involved in this project: (1) Statistical Dynamic Modeling of the Climatic Effects of Increasing Carbon Dioxide, (2) Climate Model Intercomparisons and Analysis, and (3) Scientific Director for Climate.

Task 1. LLNL is using its zonal atmospheric model (ZAM2) and a simplified one-dimensional climate/carbon-reservoir model to study the global climate response to increased atmospheric CO₂ concentrations. Although previous studies have shown that the surface temperature will increase, the intent here is to narrow the range of uncertainty by including the feedback effects on the global climate of the hydrologic balance, the vertical structure of the atmosphere, and meridional transport. The LLNL family of radiative and kinetics models will be used to improve the understanding of long- and short-wave radiation with regard to varying atmospheric composition, and to evaluate the temperature feedback effect of increased atmospheric CO₂ on stratospheric ozone.

Task 2. This task calls for an initial comparison of two models that will be used to simulate the climate's response to changes in CO₂ concentration. Although the two models are simplified to a certain degree, they each represent most of the processes likely to play important roles in determining the climatic response. By using the Livermore zonal atmospheric model (ZAM) and the Oregon State University two-level general circulation model (OSU/GCM), we propose to carry out a series of simulations to estimate reasonable upper and lower bounds on the climatic response to increased atmospheric CO₂. It is intended that these methods will serve as guidelines for conducting future evaluations and model intercomparisons as well as identifying the sources of agreement or disagreement between the models.

Task 3. Dr. Michael MacCracken serves as Scientific Director for the Climate Research Category of the Carbon Dioxide Effects Research and Assessment Program. This position was established as a means of providing DOE with a scientific researcher that can serve:

- 1) as an interface between the scientific community and those in DOE planning and,
- 2) as a technical advisor in the actual formulation of the climate research program.

Remarks: Also applies to IIA1, 2, and 4.

Category: IIA3

Carbon Dioxide⁸ Project Report

Project Title:

Funding: FY 80 \$25K

The Role of Carbonaceous Aerosol
in Climate Modification

Principal Investigator/s:

Project Number:

Rosen, H.

3703

Organization/s:

Project Monitor:

Lawrence Berkeley Laboratory

Dahlman, Roger C.
DOE, Carbon Dioxide and
Climate Division
301-353-5550

Project Summary

The purpose of this project is to:

- 1) Prepare a journal note or article for the scientific community that includes:
 - (a) preliminary findings on aerosol characteristics, concentrations, and optical properties (visible and infrared) based on analysis of the data from Pt. Barrow;
 - (b) comparison of these results to past reports of aerosol properties; and
 - (c) an assessment of the importance of the results in terms of the effects on the components of the radiation budget.
- 2) Analyze more samples from Pt. Barrow to provide information on total carbon, graphitic carbon, and the absorption coefficient for every sample. In addition, information on other chemical constituents such as trace metals, sulfate, nitrate, and organic carbon will be provided within time and financial constraints.

Category: IIA3

Note: For additional research supporting this issue refer to:

<u>Title</u>	<u>Category</u>
A Coupled Carbon Dioxide and Water Vapor Transport Model	IIA1
Enhanced Research Program on the Long-Range Climatic Effects of Increasing Atmospheric CO ₂	IIA1
Global CO ₂ Source/Sink Budget and Climatic Effects	IIA1
Research on Dynamics of the Climate	IIA4

II, A, 4

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate EffectsA. Research Subcategory: Climate Models of CO₂ Effects

4. Research Issue: Carbon Dioxide Perturbation Studies

1. Significance: There has never been a climate situation exactly like that envisioned from increasing CO₂ concentrations. Therefore, we cannot simply look back to past conditions to predict climate conditions for the future. Numerical models will have to be the primary tools used to make climate projections. It will be important, however, that several groups conduct these modeling efforts. Such parallel work by the different groups is to be encouraged since each model includes different characteristics and approaches. Coincidence of results among the groups will lend some additional credence to the forecasts, although all model results may also suffer from similar shortcomings. Any divergence of results must be examined very carefully to determine whether the differences represent model deficiencies or a lack of knowledge of the climate system.

Only within the last year have CO₂ perturbation studies begun to move beyond relatively crude simulations of annual average changes with idealized topographic and surface conditions. While these simulations tend to reinforce earlier work that Northern Hemisphere annual-average surface temperatures are likely to increase 1.5 to 3.0°C, or perhaps more, for a doubling of CO₂, they are only beginning to offer additional insight into seasonal variations, changes in precipitation patterns, and the probability of polar sea ice melting. It is these questions that are of greatest significance.

2. Program Description: The next several years offer the prospect for significant progress. Assuming that a projection of future CO₂ concentrations is independently specified, studies are needed that consider how the increased CO₂ concentrations will perturb the climate with particular attention being paid to the following questions:

- a) What is the projected, quasi-equilibrium climatic change for some specified future CO concentration (e.g., a doubling)? The projected changes should be specified in terms of seasonally and latitudinally dependent changes in temperature and precipitation.
- b) How will oceans act to modulate or alter the projected quasi-equilibrium climatic change? Will delay of the projected equilibrium response change the equilibrium response?
- c) What regional changes in climate and climatic variability will be induced by the projected global changes? Particular attention should be paid to such aspects as changes in frequency of weather patterns, frost, diurnal pattern of the variation, land-ocean differences, and influences on agricultural and water resource regions.

- d) What climatic changes will be induced in polar regions and how do these relate to changes in land and sea ice and snow cover?
- e) What changes in oceanic circulation and air-sea exchange result from the perturbed climatic conditions, and how do these changes in turn affect the climate and sea ice?
- f) To what extent are these answers dependent on the rate of change of carbon dioxide concentration?
- g) What is the degree of uncertainty in these answers, and to what extent are they dependent on the type of model and the treatment of particular processes?

Studies are needed that consider not just the changes when a new equilibrium climate is established, but also what changes occur as CO₂ concentrations are increasing. Because the natural climate is not constant, the effect of fluctuations such as those that have occurred in the past must be considered to determine whether amplification or cancellation of effects is possible when fluctuations occur in the future.

Together with analysis of data and characteristics of the present climate, a modeling approach including both GCMs and SDMs offers the potential for addressing all of these questions, at least in a preliminary way, during the next five years.

3. Priority: High

4. Participating and Funding Agencies: NOAA, NSF, DOE, NASA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Preliminary estimates of regional effects from three-dimensional model(s).	750
1981-82	Preliminary results from coupled ocean-atmosphere models.	1,500 1,700
1983	Results from comprehensive climate models, including further estimates of regional effects. Prepare draft summary report.	1,700
1984	Systematic estimates of the limits of climatic effects on a regional and seasonal basis.	1,900

Carbon Dioxide Project Report

Project Title: Funding: FY 80 \$950K

Climate Consequences of Increased CO₂

Principal Investigator/s:

Project Number:

Manabe, S.

Organization/s:

Project Monitor:

Geophysical Fluid Dynamics Laboratory,
NOAA

Manabe, S.
NOAA, Geophysical Fluid
Dynamics Laboratory
609-452-6520

Project Summary

Development of climate models to determine the equilibrium climate with concentrations of CO₂ two and four times the present concentration. The climate models consist of a General Circulation Model (GCM) of the atmosphere, a heat-and-water balance model of the continents and a mixed layer model of the ocean. Improving the spatial resolution of the model so better estimates of regional climate can be made is progressing. Improvements in the geography and cloud parameterization is also going forward.

Work on developing a coupled atmospheric GCM with an ocean GCM is proceeding to enable the transient response of the climate system to increasing CO₂ rather than only the final equilibrium state.

Carbon Dioxide Project Report

		DOE	NSF
Project Title:	Funding:	FY 80	<u>\$166K</u> <u>\$166K</u>
Research on the Dynamics of the Climate			

Principal Investigator/s:

Gates, W. Lawrence

Project Number:

7987 - DOE
ATM77-26406 - NSF

Organization/s:

Oregon State University

Project Monitors:

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572Hecht, Alan
NSF, Atmospheric
Sciences
202-357-9892

Project Summary

This involves research on climate dynamics with an emphasis on three problem areas: (1) the predictability of climate on seasonal and interannual time scales; (2) the climatic effects of increased atmospheric CO₂; and (3) the physical mechanisms responsible for the maintenance and change of climate, especially the role of long waves. These problems will be investigated through coordinated and parallel approaches involving the assembly and diagnosis of simulated and observed climatic data, the development and application of atmospheric, oceanic, and coupled atmosphere-ocean general circulation models, and supporting theoretical, numerical, and modeling research.

The research on climate diagnosis consists of the analysis and observational comparison of the various control and experimental integrations of the atmospheric, oceanic, and coupled GCMs, with emphasis on the space-time structure of seasonal and interannual variability. We will assemble monthly statistics for a ten-year period for a selected set of observed climatic variables, and will analyze the observed seasonal and interannual variability in a manner parallel to that used for model-simulated data. Other diagnosis research concerns the development of comprehensive procedures for determining the statistical significance of both simulated and observed climatic changes, and the statistical representation of local climate in terms of large-scale variables.

The research on model development consists of the design of parameterizations of cumulus convection and of the planetary boundary layer and their incorporation into the two-level atmospheric GCM, and the development of an improved oceanic GCM to include sea ice, salinity and an imbedded mixed layer. After the generation and analysis of extended control integrations, these models will be coupled into a model of the joint atmosphere-ocean system, and interannual control integrations corresponding to those performed with the separate models will be conducted.

The major application of these models will be the investigation of the climatic effects likely to result from increased atmospheric CO₂. There will be a sequence of seasonal experiments with global models differing principally in the manner in which the ocean is permitted to respond when the atmospheric CO₂ level is raised: in preliminary experiments the ocean will variously be assigned its normal seasonal variation of sea-surface temperature, treated as a swamp of zero heat capacity, or treated as a mixed layer of finite depth. The culmination of this experimental series will be an extended interannual simulation with a fully-coupled atmosphere-ocean GCM in response to progressively raised CO₂ levels.

The research in support of this diagnostic and modeling activity consists of the examination of the climatic roles of long, quasi-stationary atmospheric waves, of oceanic meso-scale eddies, of new quasi-conservative measures of the atmosphere, and of the finite-difference schemes used in numerical models. Simplified climate models will be developed by severely truncating their spectral representation and/or by coarsening their finite-difference grid, and these models will be applied in sensitivity and predictability studies in parallel with those using conventional GCMs, including examination of the climatic effects of increased atmospheric CO₂.

Remarks: Funded jointly by DOE and NSF.
Also applies to IIA1, 2, and 3.

Category: IIA4

Note: For additional research supporting this issue refer to:

<u>Title</u>	<u>Category</u>
A Coupled Carbon Dioxide and Water Vapor Transport Model	IIA1
Enhanced Research Program on the Long-Range Climatic Effects of Increasing Atmospheric CO ₂	IIA1
Global CO ₂ Source/Sink Budget and Climatic Effects	IIA1
Carbon Dioxide Effects Research	IIA3

II, B, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate Studies

B. Research Subcategory: Reconstruction of Past Climates

1. Research Issue: Paleo-Climatic

1. Significance: To supplement model results, to gain basic information about the physics of climate (e.g., interactions, oceanic lags, ice sheets, biota, etc.), and to provide additional climatic regimes against which model results can be evaluated, the CO₂ climate sub-program will support research on reconstruction and diagnosis of past climates. The research will seek to gain information from studies of a variety of past climates and climatic changes and trends and patterns in historic data. These efforts should be particularly helpful for projecting regional temperature changes and changes in related climatic parameters such as precipitation. Because recent model studies have indicated that the simulated climate responds similarly to various warming influences (e.g., increased CO₂, increased solar radiation), it may be appropriate to assume that understanding gained from studies of past warm climates (for which we do not know the cause) may be useful in projecting ahead to the future warm climate conditions that CO₂ is expected to induce. However, current knowledge of the paleoclimatic record remains very limited and the need for information to use in testing numerical models is great, so that it would be premature to strictly limit the scope of paleoclimatic research to particular "analog" or time intervals.

Such paleoclimatic data as pollen and glaciologic records and ocean sediment cores have shown that the warmest part of the hypsithermal--a period from about 5,000 to 7,000 years ago--was considerably warmer (1 to 2 K) than present in the North Atlantic basin and neighboring continents. This period offers one opportunity for the expanded analyses that are necessary to better document the global effect and regional variations to be expected from a warming. By also looking at the variety of major climate changes over the last 20-30,000 years, including the most recent glacial maximum (18,000 YBP) and transitions to the maximum interglacial (5-7,000 YBP), additional insight can be expected.

It is interesting that in attempting to reconstruct past climates, we are actually doing so by looking at the environmental and ecological effects of past climates. Thus, this aspect of the climate research effort is tied very closely to effects studies, and may offer very useful insights on the analysis of model results in terms of ecological impacts.

2. Program Description: The global climate is believed to have been warmer than present for most of the earth's existence, but colder than present during most of the past two million years. The most recent warm periods were during the last interglacial (the Eemian-Sangamon some 110,000 years ago) and during the maximum of the current interglacial, sometimes referred to as the hypsithermal (5,000-7,000 years ago). There is substantial interest in the former period as a means for investigating the onset of a major glacial period,

particularly because sea level was 5-6 m higher than present, indicating that one or more of the polar ice sheets must have been smaller. Data on the period, however, may be too sparse to yield regional climate patterns in the near future.

Data are even more difficult to reconstruct for the much warmer Tertiary period, the time more than 20 million YBP, before the Antarctic continent acquired its ice sheets. The period between about 20 million YBP and 5 million YBP may be of particular interest, however, because there was a marked asymmetry in the hemispheric climates due to the fact that the southern polar regions were glaciated and the northern polar regions were not. Such a situation could recur with a CO₂ warming, and its general circulation patterns might be quite different than the present.

The maximum in the recent interglacial, or hypsithermal period, may offer substantial information. Analysis of sediment cores should provide extensive information on ocean surface temperatures, patterns of major currents, sea ice extent, and glacial volume. Glaciologic investigations can provide information on annual variations, if enough information is available on present hydrologic conditions. Efforts to fill gaps in the existing records, particularly in the Pacific basin and the Asian mainland, and to provide better temporal resolution using land and marine data should be able to improve understanding substantially during the next decade.

The program will work with other government agencies to encourage research into those aspects of the climate of these periods that may bear on the CO₂ issue. Particular effort will focus on assembly and analysis of existing data, investigation of the mechanisms governing warm and warming periods, evaluation of the time constants controlling climatic response, and preparation of data bases for model verification.

Just as with model results, it will be important that great care be taken in paleo-climate analysis. Complicating factors include limitations on temporal and spatial coverage and resolution, effects of potential competing influences (e.g., different solar orbital effects, sunspots, volcanic conditions, etc.), and identification of changes in variability as opposed to changes in the mean climate. Moreover, we do not yet know the causes of past changes and so may not appreciate fully the differences that may be induced when CO₂ is the perturbing factor. If at all possible, therefore, we should seek to gain understanding of the causes of past changes--not just of the changes themselves.

3. Priority: Reconstruction of paleoclimates of the last 30,000 years with particular emphasis on aspects that will provide insight into the climatic changes that may be induced by increasing CO₂. High

4. Participating and Funding Agencies: NSF, DOE, USGS

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Expand area studies of the hypsithermal and other climates and climate changes of the past 20-30,000 years, using pollen, sediment, and glaciological features as indicators of past environmental conditions.	200
1981	Survey data from hypsithermal period to find regions where early indications of warming conditions appeared.	300
1982	Continue studies, looking at regional changes that occur in major climatic transitions, with increased emphasis on the Pacific basin and Asian mainland.	400
1983	Integrate knowledge about climatic behavior gained from studies of past climates and develop composite estimates concerning characteristics of future warm climates. Prepare draft summary report.	500
1984	Continue studies and participate in development of integrated CO ₂ scenario.	500

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$25KCOHMAP (Climates of the Holocene:
Mapping Based on Pollen Data)

Principal Investigator/s:

Project Number:

Webb, Thompson III

ATM79-16234

Organization/s:

Project Monitor:

Brown University
University of Minnesota
University of WisconsinHecht, Alan
NSF, Atmospheric
Sciences
202-357-9892

Project Summary

Over the past two years (1977-1979), investigators have collected, compiled, and mapped pollen data from North America and the Soviet Union. At the same time, they have calibrated and mapped these data in climatic terms and have compiled and mapped many types of terrestrial geological data from 18,000 years BP in order to document the full glacial global climate and to validate computer simulations of climate at this time.

Over the next two years, COHMAP investigators will continue to: (1) collect new pollen data and compile available pollen and other geological data; (2) calibrate pollen data in climatic terms from both general records of the past 12,000 years and detailed records of the past 3,000 years; (3) calibrate lake-level data in climatic terms; (4) synthesize the pollen and paleoclimate data into contoured maps over both small regions and large sub-continental areas; and (5) model work with inexpensive computerized climate models whose results can be checked against the calibrated data and maps and can serve as preliminary planning for general circulation model experiments. Ultimately, the project aims to map detailed changes along climatically-sensitive ecotones as well as broadscale climate changes over most of eastern North America and large parts of the Northern Hemisphere.

Category: IIB1

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$212K

Global Temperature Patterns 6,000 Years Ago

Principal Investigator/s:

Project Number:

Webb, Thompson III

7874

Organization/s:

Project Monitor:

Brown University

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

The purpose is to assemble contoured climatic maps for the "Hypsithermal" period 5,000 to 7,000 years ago in the Northern Hemisphere. This project includes researchers both in palynology and paleo-oceanography from the U.S. and Europe and funds the synthesis of available paleoclimatic data from North America, Eurasia, Africa, and the North Atlantic and North Pacific Oceans.

Established calibration techniques will be used to transform the pollen and marine plankton data into quantitative estimates of temperature, moisture, and atmospheric circulation. Mapping these estimates will allow construction of contours and depiction of the climatic patterns from 5,000 to 7,000 years ago. Work will focus on mapping and calibration of the available geological data from western and northeastern North America, from eastern and northern Africa, from Europe, and from the North Atlantic and North Pacific Oceans.

Category: IIB1

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II, B, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate Studies

B. Research Subcategory: Reconstruction of Past Climate

2. Research Issue: Historic Climate

1. Significance: If our understanding of the atmosphere-hydrosphere-cryosphere-biosphere system were complete and if model results compared with data on past climates so that confidence could be placed in model predictions, then we could rely solely on numerical models to simulate the climatic effects of increasing CO₂. Unfortunately, we do not understand any of these systems sufficiently accurately to be able to assure that our models will yield the proper magnitude, perhaps even the sign, of all of the individual climatic responses. Thus, although a model may indicate a 3°K average annual warming for the Northern Hemisphere, regional effects may be larger, smaller, or of opposite sign; precipitation at a particular location may increase, decrease, or change its seasonal distribution; and ocean fishing conditions may improve or deteriorate.

By using the experience gained by analysis and observation of the atmosphere, the rather generalized model results can be evaluated and used to develop more detailed estimates. For example, relationships between the climates of large and small regions should be useful in providing indications of changes in critical regions. The variability of recent climates also offers a means of testing the quality of the numerical models that are being used. In particular, testing the models against possible explanations of the climatic warming earlier this century may be a means of verifying whether atmospheric feedback processes are being properly modeled.

2. Program Description: Historic data, much of it indirect, indicate that a several-hundred-year period about a thousand years ago was slightly warmer than the present, particularly in the Atlantic basin. Since that time there have been several periods lasting a few decades that have been warm, but in general the climate has been somewhat cooler (up to 1 K) than present. While the changes are therefore somewhat smaller than between the present and the warmest times of the hypsithermal, there is the opportunity to estimate the potential climatic effects of increasing CO₂ by contrasting warmer and cooler periods using considerably more accurate data and over a time scale better matched to the CO₂ issue.

A second historic warm period occurred in the first few decades of this century, when temperatures were perhaps a few tenths of a degree warmer than at present. Analysis of the regional nature of the changes, which resulted in dust-bowl conditions in the U.S. plains, may provide important insight into possible patterns of climatic response and changes in frequency of occurrence of various weather patterns. Efforts can also be made to develop climatic composites that reflect the behavior of the warmest years of this period. Although such composites will not reflect the ultimate changes in the equilibrium climate that might be expected as CO₂ increases, the nature and location of regional changes may at least indicate the sign and magnitude of possible responses.

3. Priority: Analysis of climates of the last thousand years, particularly in the last hundred years, to improve understanding of the global and regional nature of climate and its fluctuations and variability. High

4. Participating and Funding Agencies: NSF, DOE, NOAA

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Initiate exploratory studies of climate of last 100 years to identify and characterize warm years and warm seasons.	100
1981	Initiate comprehensive study of the climate of the 1930s and 1940s, with emphasis on continental and global descriptions of the "Dust-Bowl Era".	150
1982	Continue study with focus on major agricultural and water resource areas. Survey data from dust bowl period to find regions where and how the early indications of warming conditions appeared.	200
1983	Integrate knowledge about climatic behavior gained from studies of past climates and develop composite estimates concerning characteristics of future warm climates.	300
1984	Continue studies and participate in development of integrated CO ₂ scenario.	350

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$75K

Bioclimatology of Energy Impacts

Principal Investigator/s:

Project Number:

Blasing, T. J.; Solomon, A. M.

3160

Organization/s:

Project Monitor:

Oak Ridge National Laboratory

Osburn, William O
DOE, Ecological Research
Division
301-353-4903

Project Summary

Objective: to develop, organize, and disseminate information relating climatic modifications by energy systems to associated responses of biological systems. Approach: (1) relate proposed global-scale climatic changes to variations in seasonal weather patterns over specific regions including major agricultural and forest regions; (2) express, in quantitative terms, the responses of both cultivated and native plants to climatic variations in their respective regions; (3) relate past climatic variations to their associated biological responses in order to validate the quantitative expressions of plant/climate relationships obtained under (2) and to explore possibilities for using past biotic variations (as evidenced by fossil pollen assemblages and tree ring widths) to increase knowledge of natural (pre-industrial) climate variability.

Category: IIB2

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$59K

Geographical Patterns of Climatic Change

Principal Investigator/s:

Project Number:

Wigley, T. M. L.; Lamb, H. H.

7873

Organization/s:

Project Monitor:

University of East Anglia

Moses, Harry
DOE, Carbon Dioxide and
Climate Division
301-353-5572

Project Summary

The main aim of the project is to determine the geographical patterns of past warm or warming periods as possible analogues for a future warmer world. The original aim of the project was to examine in detail the period 1000 BC to the present. Recent work has been directed towards the period 800 AD for which there are sufficient data to obtain a time resolution of 50 years. The main periods of interest are the warmth of the medieval warm Epoch (which lasted from approximately 800-1200 AD), the climate of The Little Ice Age (about 1550-1700 AD) as a possible "negative analogue", and the present century.

Category: IIB2

II, C, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate Effects

C. Research Subcategory: Climate Scenario Development

1. Research Issue: Climate Scenario Development

1. Significance: To allow an encompassing evaluation of the environmental and societal consequences resulting from increasing CO₂ and consequent climate changes, it is essential to develop a comprehensive estimate of changes in many climate parameters. As a minimum, such a scenario (or perhaps maximum and minimum change scenarios) must include estimates of changes of such parameters as regional and seasonal variations of temperature and soil moisture in agricultural and watershed areas; extent of sea-ice, shelf-ice, and mountain snow; and wind stress, ocean currents, and temperatures in areas of substantial oceanic productivity. Additional factors that must be estimated will be identified in coordination with those carrying out the assessment studies.

2. Program Description: This scenario should be based on an integrated inter-comparison of the climatic changes projected by use of validated models, analysis of past climates, and extrapolation of current trends. Such an effort will be an important step in looking for internal consistency of results, for confirmation of projected changes from various modeling and historical approaches, and agreement of recent trend data with anticipated changes. The effects of using various types of models, each with their own particular assumption and parameterizations, will need to be considered so that possible changes are not prevented and predicted changes are not merely artifacts. It is essential that scenarios for both maximal and minimal CO₂ effects be developed so that limits can be placed on possible societal impacts. Because most approaches will initially be considering climate equilibrium situations (e.g., a past warm period or a model simulation of doubled CO₂) and not the conditions occurring as the climate evolves from the present to that state, it will be essential to estimate rates of change and the likelihood that climate change is not continuous (i.e., that the climate is transitive).

In addition to developing a consensus scenario on the climatic effects of increasing CO₂, it will be important to determine how dependent this projection is on other factors that may potentially affect the atmosphere. There are indications, for example, that increasing concentrations of fluorocarbons will decrease stratospheric ozone. The cooling of the stratosphere that can be expected from increasing CO₂ will, however, tend to increase stratospheric ozone, thereby helping counter the effect at high altitudes. On the other hand, fluorocarbons and some other emitted gases (sometimes acting through secondary species the gases interact with chemically) tend to reinforce the CO₂ climatic modifications in the lower atmosphere since these gases also tend to absorb and re-radiate infrared radiation. Aerosols, including those emitted at the surface, formed from gases in the atmosphere, or injected to high altitude by volcanoes, can also affect the atmosphere's radiative balance, and thereby the climate. Just as projecting CO₂ concentrations and climate changes is subject

to uncertainty, these further evaluations will also involve uncertainties. It will still be important, however, to address these questions.

A variety of approaches will be used, including evaluation of past warm periods using paleoclimatic and historical data, trend extrapolation (e.g., extension of changes from 1880 to 1940), selection of warmest decade and/or warmest years, etc. Climatic changes found to be common to these different approaches and to model results will be used to construct a set of likely scenarios. Particular attention will be paid to regions where impacts may be economically or ecologically significant (e.g., agricultural regions, watersheds, mountain snow, etc.), to the seasonal effects, and to correlations of changes between regions.

3. Priorities: Intercomparison and evaluation of climate model results as a means of identifying model inadequacies, estimating uncertainties and placing limits on expected climatic change. Very High

Development of criteria and methods for interfacing data on past climates with model results in development of climatic scenarios. High

Evaluation of other natural and societal factors that may enhance or modulate the expected CO₂-induced climatic changes. Medium

4. Participating and Funding Agencies: DOE

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1981	Workshop on methods for estimating regional climatic effects; specification of "key" agricultural and watershed regions and initiation of historical studies of detailed conditions in these regions.	200
1982	Evaluate preliminary estimates of regionalized climate changes in limited number of key agricultural areas from modeling studies.	300
1983	Integrate preliminary estimates of regionalized CO ₂ -induced climatic effects from a variety of approaches (models, paleoclimate, historic, trends) in key agricultural areas. Prepare draft summary report.	400
1984	Composite estimates of regionalized climatic changes in key agricultural and watershed areas.	400

II, D, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

II. CO₂ Research Category: Climate Studies

D. Research Subcategory: Evidence of Climate Change

1. Research Issue: Evidence of Climate Change

1. Significance: The complexity of the surface-atmosphere system, the constraints of current understanding, and the recognition that even the unperturbed climate will vary all limit our ability to use models and past climatic data to provide accurate projections of the climate into the future. It is therefore essential to seek confirmatory evidence in the current observational record. Early identification of the predicted changes would provide significantly increased confidence in the projections of later, larger changes.

Current model estimates suggest that the earth should have experienced a few tenths of a degree warming since the late 1800s due to the increase of CO₂ concentrations from about 290 to the current 335 ppm. While the variation in decadal-average Northern Hemisphere temperatures during this period has been about half a degree, the overall change over this period has been very small. Further, since the warmest decades during the last century were the 1930s and 1940s, it is not straightforward to identify the supposed CO₂-induced change, which should be a monotonic increase. Thus, it appears that natural variations, perhaps related to such factors as intensity of volcanic activity or sunspots, currently are large enough to mask the expected CO₂ variation and that the thermal inertia of the oceans may be delaying manifestation of the rising CO₂-induced equilibrium temperature change. While a few researchers suggest that we should be able to start identifying CO₂-climate signals in the near future, most experts believe that an unambiguous climatic signal of CO₂-induced effects might not be evident until the year 2000, assuming that emission trends continue and the computer forecasts are correct. A critical question is whether more refined analysis of observations may find a statistically significant signal sooner than the year 2000 so that increased confidence can be placed in model results.

2. Program Description: There are some indications that identification of the projected climate changes may be achievable within the next 20 years. Very large temperature responses (approximately 10 K) are projected in polar regions and the equatorial stratosphere for a doubling of CO₂. Although natural fluctuations are quite large in polar regions, we may be able to identify and isolate some of the causative factors. In the equatorial stratosphere, the data base is rather limited, but natural fluctuations are apparently rather small. (Fluorocarbon-induced effects, however, may act in an opposite sense, thereby making signal identification more difficult.) Finding a CO₂-induced signal in this region, however, will mainly verify the radiative prescriptions used in numerical models, and may add little confidence to projections of regional changes at the surface. Certainly, projected changes in these and other parameters are developed as part of the scenarios (e.g., intensity of the hydrologic cycle, snow-line, sea-ice and permafrost extent, properties of polar air masses,

etc.) need to be compared with the observational data base in order to identify particularly sensitive indicators. It may also be useful to look at sets of parameters from the scenarios to determine whether their coupled response is in agreement with observations.

Results of these studies may point to improvements needed in current observational networks (e.g., more frequent sampling in the stratosphere, of clouds, or in polar regions). Such monitoring should be directed at providing early warning of the anticipated changes or, if absent, might reassure us that the changes have been overestimated.

3. **Priorities:** Identify parameters believed to be most sensitive to CO₂-induced climatic change and estimate the likelihood that the change can be identified with confidence; ensure the adequacy of the data base. High

Expand statistical analyses of present and past climatic data in order to identify CO₂-induced climatic changes. Medium

4. **Participating and Funding Agencies:** DOE, NOAA

5. **Milestones and Budget:**

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1981	Workshop on possible research approaches to developing evidence for CO ₂ -induced climate change. Identification of key variables of interest.	50
1982	Expand the present limited studies.	100
1983	Preliminary statistical studies and evaluation of key variables. Prepare draft summary report.	100
1984	Preliminary evaluation of extent of change of key variables, if any.	150

III. Research Issues in the Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Effects on the Cryosphere, Oceans, and Marine Biota

B. Effects on the Terrestrial Biological Resources

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$361K</u>
Research Plan on the Environmental and Societal Impacts of a CO ₂ -Induced Climate Change	
Principal Investigator/s:	Project Number:
Burns, David M.	8057
Organization/s:	Project Monitor:
American Association for the Advancement of Science	Gerhardt, Paul DOE, Carbon Dioxide and Climate Division 301-353-4374

Project Summary

This involves the development of options for research to determine the environmental and societal consequences of a possible CO₂-induced climate change. Specifically, the work will spell out the research needed, and will establish the objectives, priorities, time frame, and level of support suitable for a 10- to 20-year national plan. The options presented should narrow the uncertainties and facilitate decisionmaking.

Remarks: Also applies to Category IV.

Category: III

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$14K

The Consequences of a Hypothetical
World Climate Change Produced by
Increased Atmospheric Carbon Dioxide

Principal Investigator/s:

Project Number:

Roberts, Walter Orr

8176

Organization/s:

Project Monitor:

Aspen Institute for Humanistic Studies

Gerhardt, Paul
DOE, Carbon Dioxide and
Climate Division
301-353-5125

Project Summary

This project involves a one-year preliminary analysis of the effects of CO₂ on human societies and human choices, with the objective of identifying participants, problems, methodologies, and timetables for a longer, cooperative, sustained effort to discover how to meet this urgent environmental problem in ways that minimize any adverse effects. The proposal derives from discussions at a week-long planning workshop held at Aspen, October 8-14, 1978.

Category: IIIA

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III, A, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Research Subcategory: Effects on the Cryosphere, Oceans, and Marine Biota

1. Research Issue: The West Antarctic Ice Sheet

1. Significance: The West Antarctic ice sheet is believed by some glaciologists to be unstable. CO₂-induced warming, amplified in the polar regions, might cause it to disintegrate, leading to a worldwide rise in sea level that would inundate many coastal cities and much valuable agricultural land. Estimates need to be made of the probability of ice sheet collapse and the approximate rate at which this might occur.

2. Program Description: Deep drilling should be done in the West and East Antarctic ice sheets to determine the sequence and timing of ice formation and deglaciation, especially during the period approximately 120,000 years ago when West Antarctic is believed to have been substantially deglaciated. New drill equipment must be developed capable of penetrating depths greater than 1,000 meters. A literature search and field studies should be undertaken to locate and date wave-cut and depositional terraces above present sea level. Detailed studies of the Amundsen Sea Drainage Basin (especially Pine Island Glacier) and the Ross Sea Drainage Basin should be undertaken to determine present rate of ice flow and the relationship of this rate to the physical properties of the ice.

3. Priority: High for all of the above.

4. Participating and Funding Agencies: NSF

5. Milestones and Budget:

Fiscal Year

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III, A, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Research Subcategory: Effects on the Cryosphere, Oceans, and Marine Biota

2. Research Issue: Northern Hemisphere Sea Ice and the Arctic Ocean

1. Significance: General circulation models of the earth's atmosphere indicate that a four-fold increase of atmospheric CO₂ levels would cause the ice covering the Arctic Ocean to disappear, at least in summer. This could possibly cause profound changes in oceanic and atmospheric circulation. In order to estimate the likelihood of this event and the possible consequences, greater understanding is needed of the dynamics of formation and dissolution of sea ice in the Arctic Ocean and the surrounding seas and of the interactions between the sea ice and underlying waters.

2. Program Description: Research should include monitoring to provide data on the current seasonal and interannual fluctuations of the extent of northern sea ice. Data should also be gathered on the wind stress field, and on heat exchange between ocean water and sea ice, and between sea ice and the atmosphere. This program will involve placement of data buoys, analysis of satellite images and other sea ice data; a study of water-exchange characteristics in the Fram Strait; studies of Arctic Ocean circulation patterns using tracers, data buoys, and water samples; examinations of the oceanographic and climatological significance of land-sea interactions; determinations of the effect of sea ice on the uptake and downward convection of CO₂ in polar oceans; and improved modeling of Arctic Ocean dynamics.

3. Priority:

4. Participating and Funding Agencies: NOAA, DOD

5. Milestones and Budget:

Fiscal Year

Milestones

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III, A, 3

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Research Subcategory: Effects on the Cryosphere, Oceans, and Marine Biota

3. Research Issue: Tundra, Taiga, and Permafrost

1. Significance: With a sufficient increase in atmospheric CO₂, climatic warming of 5-10°C. might occur in high latitudes. This could result in extensive thawing of permafrost, with marked effects on the hydrology and ecology of the tundra. These areas of frozen ground contain large reservoirs of organic carbon in peat deposits, and probably also in methane hydrates a few hundred feet below the surface. Thawing of the permafrost could result in oxidation of the peat and release of methane gas, and thus in a positive feedback effect on atmospheric carbon dioxide. Scientific cooperation with Canada and the USSR is necessary because of the vast areas of frozen ground within these countries.

2. Program Description: Research should include: monitoring temperature changes in and over the permafrost; climatic interpretations using existing data on solar radiation, air temperature, wind velocity, cloud cover, humidity, and precipitation; interpretations of paleoclimatic data to determine whether past climatic conditions closely approximated the permafrost conditions that might occur in a high-CO₂ world; field interpretations of peat thicknesses and vegetation types and of thaw lakes; socioeconomic studies of effects on northern animals; and analyses of the amount of methane in permafrost and whether thawing would expose large reservoirs of organic carbon to oxidation.

3. Priority:

4. Participating and Funding Agencies: USGS, DOD

5. Milestones and Budget:

Fiscal Year

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III, A, 4

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Research Subcategory: Effects on the Cryosphere, Oceans, and Marine Biota

4. Research Issue: Upper Ocean Circulation Patterns

1. Significance: A CO₂-induced warming of the lower atmosphere and associated changes in surface winds could alter the horizontal motions of the ocean waters and vertical and horizontal diffusion between ocean layers. This in turn would affect the transport and storage of heat and carbon dioxide in the oceans. Changes in heat transport between low and high latitudes could affect coastal weather patterns, fisheries, and northern ecosystems. Changes in heat and carbon dioxide storage in the oceans could affect the magnitude and timing of climate change. These changes need to be considered in present models and predictions.

2. Program Description: Detailed studies of the mechanisms and dynamics of present upper oceanic circulation patterns under present conditions will be undertaken to improve understanding of the nature of possible CO₂-induced changes. This would include research on vertical mixing at high latitudes and mixing and advection along surfaces of constant density. Support will also be given to the "CAGE" experiment being undertaken jointly by the Intergovernmental Oceanographic Commission and the Scientific Committee on Oceanic Research to measure the meridional heat transport in the North Atlantic. Finally, analogues to a "high-CO₂" world will be sought in the past, primarily by studying ocean and lake sediments in the Altitheermal Period.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

Note: For additional research supporting this issue refer to:

Title

Category

Geological Perspectives on Global CO₂

IA6

III, A, 5

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

A. Research Subcategory: Effects on the Cryosphere, Oceans, and Marine Biota

5. Research Issue: Marine Biota

1. Significance: A warming of the ocean surface could increase the vertical stability of ocean waters and diminish the upwelling of nutrients. An increase in carbon dioxide could increase the net primary production of phytoplankton. It would also decrease the pH of surface seawater. This may alter the composition of the phytoplankton community, and consequently the oceanic food web and populations of fish and other organisms useful to man. Additionally, the sedimentation of organic carbon on continental shelves and to the deeper ocean might be affected, removing as much as one gigaton of carbon per year from the overall carbon flux.

2. Program Description: Research is recommended on:

- a) Changes in the stability of the water column. Will primary production be affected by decreased upwelling and greater water-column stability? We need (1) theoretical studies of the upper turbulent boundary layer, seasonal descriptions, and determination of sensitivity of heat distribution to convective and evaporative heat exchange and rates of turbulent energy input; (2) theoretical studies of the effects of mixed layer movement on nutrient transport; (3) analysis of existing and new data on seasonal changes in mixed layer, euphotic, and nutricline depths to predict planktonic changes; (4) sea surface temperature and color, via remote sensing, to detect climatically-induced shifts in production; (5) experiments using tracers of nitrogen to examine rates of ammonification and nitrification and the response of bacterioplankton; and (6) examinations of paleological records such as phosphalite as an analogue of biological effects of changes in upwelling.
- b) Primary production in phytoplankton. Effects of higher CO₂ concentrations on different groups of phytoplankton should be studied both in laboratory cultures and ocean "microcosms." Laboratory studies should include: (1) reductive TCA cycle, and C₄ cycles; (2) enzymatic considerations, including carbonic anhydrase; (3) relation of cell morphology and anatomy to functional aspects of organelles; (4) membrane transport, including uptake, ion pumps, etc.
- c) pH levels and phytoplankton, zooplankton, and fish larvae. Laboratory and ocean-microcosm experiments should determine the effects on marine life of lower pH levels. We also need to understand the chemical activity of important nutrients, including ionic species, complexation reactions, and ligand binding constants. Laboratory and controlled

field studies should investigate: (1) biochemical/enzymatic studies of isolated enzyme systems; (2) membrane-bound transport systems maintained by light-mediated electron transport by marine flora; (3) sensitivity to change in CO₂-pH of representative marine zooplankton, invertebrates, and fish larvae; (4) long-term effects of lowered pH on macrophytes and benthic communities and possible resultant shifts in community structure.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

III, B, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Biological Resources

1. Research Issue: Direct Biological Effects of Increased Atmospheric CO₂ on Plants

1. Significance: Major questions must be resolved concerning the direct biological effects of elevated levels of atmospheric CO₂ on agricultural crops, weeds, forests, marine and freshwater plants, rangelands species, and microorganisms. The CO₂ phenomenon will have wide-ranging impact on all biospheres, and thus represents an issue of global significance. It relates directly to optimization of the productivity of agriculture, rangelands, and forests and fisheries. One of the principal benefits of increased atmospheric CO₂ might be higher photosynthetic productivity and water-use efficiency in cultivated crops. Studies should be undertaken to determine whether varieties of field crops can be developed that will have higher net photosynthetic production and use less water as atmospheric CO₂ content increases.

2. Program Description: Research should consider three principal questions: (1) How will biological processes such as photosynthesis, nitrogen fixation, transpiration, and reproductive development respond to an undirectional increase in atmospheric CO₂? (2) Can genetic types be developed to take better advantage of CO₂ fertilization? (3) How can management practices be altered to make use of increased atmospheric CO₂? An international conference on the biological effects of CO₂ on plants should be convened. Approximately 200 scientists representing a wide variety of disciplines should deal with the following topics: marine biota; grazinglands and range; forest ecosystems and productivity; freshwater ecosystems; soil microbiology; agricultural productivity; water-use efficiency; and weeds. Conference participants should recommend high-priority research projects regarding direct biological effects of CO₂ increases, and also suggest methodologies and funding levels. Along with the planning and convening of the conference, specific research projects should be undertaken in the following areas: (1) differential biological responses to high levels of CO₂ on genetic variants of major food, forest, range, and weed species; (2) responses of major food, forest, range, and weed species grown under conditions of high CO₂ coupled with different environmental stresses; (3) how water-use efficiencies of plants are modified under various levels of atmospheric CO₂; (4) effects of elevated CO₂ levels on soil and water microorganisms; (5) response of noncultivated ecosystems to CO₂ enrichment; and (6) stimulation of aquatic productivity by additional CO₂.

3. Priority: International conference on direct biological effects of CO₂ increases. High

4. Participating and Funding Agencies: DOE, NSF, USDA, FAO

5. Milestones and Budget:Fiscal YearMilestonesBudget

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$150KPlant Responses to Increasing Global
Carbon Dioxide Concentration

Principal Investigator/s:

Project Number:

Strain, Boyd R.; Hellmers, Henry

DEB78-23640

Organization/s:

Project Monitor:

Lance, John
NSF, Earth Sciences
202-357-7915

Project Summary

This research project will be conducted in the Duke University Phytotron facility to investigate the effects of increased carbon dioxide (CO₂) on plant growth over several successive generations. Standard seeds of various legumes obtained from the USDA will be used for the experiments for the first year. Subsequently various herbaceous and woody plants will be incorporated into the research design, as well as structuring of mechanistic models from the data. Three concentrations of CO₂ will be used during the experiments; (a) ambient or ca. 330 ppm, (b) 660 ppm, and (c) 1,000 ppm. The plants all will be grown and tested for photosynthetic activity under high light intensity (ca. daylight conditions at 2,400 Einstein's m⁻²s⁻¹, photosynthetically active radiation (PAR). Infrared gas analyzers will be used to determine CO₂ exchange in whole plants as a measure of photosynthesis. Many of 31 widely recognized and recently reported plant responses to CO₂ enrichment will be measured and used as parameters for monitoring the experiments. In addition, the levels of nitrogen in shoots and roots will be examined in order to obtain C/N ratios as a function of the experimental regime. The research is aimed at providing badly needed measurements that can be used to predict natural events during any ensuing increase in global CO₂. To aid the definition and analysis of this research and to provide early dissemination of results to groups working on other phases of the effects of global increases in CO₂, a series of three workshops will be conducted over a three-year duration of the project. The first will examine facilities and mission of projects involved with biological effects of global CO₂ increase, the second will examine carbon lock-up and turnover, and the third will examine long-term prediction. Key scientists from various universities and governmental agencies and laboratories involved with global carbon will participate in the workshops.

Category: IIIB1

Carbon Dioxide Project Report

Project Title: Funding: FY 80 \$78K

Microclimate-Plant Architecture Interacting
Effects on Photosynthesis, Evapotranspiration
and Water Use Efficiency

Principal Investigator/s:

Project Number:

Rosenberg, N.; Verma, S.

ATM79-01017

Organization/s:

Project Monitor:

University of Nebraska

Hecht, Alan
NSF; Atmospheric
Sciences
202-357-9892

Project Summary

A systematic program of research is to be conducted in which the plant architecture influences on the exchanges of energy and mass within and over a crop canopy will be studied throughout the entire growing seasons. The experiments will be conducted with soybeans--a crop of major economic importance. Vertical distributions of the fluxes of water vapor, carbon dioxide and sensible heat will be measured within and above canopies of isogenic crop cultivars with distinctly different morphological characteristics. The contributions of soil, root, and crop respiration to the carbon balance of soybeans will also be studied. Simultaneous observations will be made of pertinent soil and plant characteristics (e.g., soil moisture, plant height, leaf area index, crop temperature, plant water potential, and stomatal resistance). The relationships of the turbulent exchange coefficient for carbon dioxide with the exchange coefficients for water vapor, sensible heat and momentum will be determined under a variety of environmental conditions including sensible heat advection. The studies will be conducted at a well-instrumented agricultural meteorology research station located near Mead, Nebraska--a site characteristic of the east central Great Plains and of other important sub-humid to semi-arid food producing regions of the world. Recommendations will follow from these studies of ways to beneficially alter the canopy-microclimate system in order to maximize water efficiency. Data accumulated will serve as the basis for critical tests of physical and mathematic models which describe the exchange of energy and matter within and above crop canopies.

Category: IIIB1

III, B, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

2. Research Issue: Biological Monitoring

1. Significance: Biological monitoring permits the evaluation of model predictions and the general identification of biological responses to climate changes and rising CO₂ levels.

2. Program Description: Steps will be taken to utilize and strengthen existing networks for biological monitoring, including UNESCO's Biosphere Reserves Program, the U.S. Forest Service's Continuous Forest Inventory Program, and the Natural Resource Inventory Program administered by the U.S. Bureau of Land Management. Additional monitoring of sites at forest ecotones and core regions will be undertaken to gain information on relationships between climate changes and forests.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

3. Research Issue: Growing Seasons

1. Significance: A climate change would entail substantial changes in the nature of growing seasons in most regions. Considerable dislocation and disruption of agriculture might result.

2. Program Description: An impact assessment of agricultural growing seasons within and across various latitude belts in the Western Hemisphere will be conducted using historical data. This study will include analysis of potential impacts on the major grain and oil crops of simulated annual and growing season temperatures based on predictions from climate models. Emphasis will be given to the corn and soybean belts and rangelands in North America, the winter-wheat belt, tropical rangelands, and rain forests in South America, and specialty crops throughout.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

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III, B, 4

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

4. Research Issue: Environmental Stress on Renewable Resource Productivity

1. Significance: Climate changes that are likely to accompany rising levels of atmospheric carbon dioxide will produce environmental stresses in many crop plants resulting from higher average and extreme temperatures, and possibly also from lower water availability possibly combined with the presence of atmospheric pollutants, unfavorable soil nutrient levels, increased soil alkalinity, or higher soil salinity. Research should proceed along three lines: studies of the basic biology of plant response and resistance to environmental stresses; genetic manipulation of crop varieties for greater resistance to environmental stresses; and development of production-management systems that maximize the expression of genotypic stress resistance.

2. Program Description: Research should be performed on the fundamental mechanisms by which some plants are disadvantaged by environmental stresses while other plants can tolerate such stresses. Research should proceed at all levels, from biochemical to whole-plant responses. Important to this effort is improvement in local and area-wide measurements of moisture status in plants and soil (microwave and infrared sensing at various heights, from the ground to satellites, offer great potential). Major food crops should be genetically manipulated to improve their resistance to temperature and water stresses. An analysis is needed of the optimum range of production for agronomic and horticultural crops. Finally, research should focus on the special problems of woody perennials, including tropical varieties, regarding temperature and moisture stresses.

3. Priority: Research into the basic biology of plant response and resistance to environmental stresses. High

4. Participating and Funding Agencies: USDA

5. Milestones and Budget:Fiscal YearMilestonesBudget

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III, B, 5

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

5. Research Issue: Plant Protection

1. Significance: Pests, including weeds, insects, diseases, and nematodes, are climatically adaptive as well as climate specific. In particular, many are temperature dependent. A CO₂-induced climate warming is likely to increase pest problems significantly, which at present inflict enormous losses on food crops. There may also be implications for human and animal health.

2. Program Description: Controlled environment studies will be conducted of several noxious weeds to determine their response to increases in temperature and CO₂ levels. Literature on the impact of temperature changes on sporulation and penetration of diseases through or in plant stomates will be reviewed. The aquatic weed Hydrilla verticillata which apparently can rapidly deplete soluble carbon dioxide in shallow waters will be examined to determine its response to increased CO₂ levels or altered climatic conditions. A simulation model employing existing population dynamics data will be developed to ascertain the extent of migration and rate of increase of the fire ant. A simulation model using existing data on the Cereal Leaf Beetle and the Fall Webworm will be developed with simulated climatic data from a climate model, with a view towards generalizing the model to other pests. The impact of climate changes on pest management strategies, in particular on decisions as to when and how to protect against pests, will be investigated using a two-system validation approach with onions and field beans. The effects of increased temperatures on cutworms and armyworms that afflict corn and wheat and on root-knot nematodes, a major food and fiber crop pest, will be examined.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

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III, B, 6

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III, CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

6. Research Issue: Agriculture in Developing Countries

1. Significance: The traditional agricultural systems of many developing countries will be especially vulnerable in regions where CO₂-induced climate change caused increased aridity. Although temperature increase may be less in the tropical than in temperate latitudes, special problems and opportunities will likely be associated with any changes such as precipitation patterns. For example, relatively slight climatic shifts may increase (or decrease) possibilities for multiple cropping.

2. Program Description: Research is needed regarding the productivity and resilience of tropical agriculture. Tropical agricultural research must take account of the social and institutional structure in each locality, as well as biological resources and management techniques, assuming plausible but unknown changes in climate patterns. Agricultural research in the tropics should take explicit account of the possibility of climate change both in genetic selection and management practices. It should also be planned to take advantage of the expected increase in atmospheric CO₂ as it may directly stimulate plant growth.

3. Priority:

4. Participating and Funding Agencies: Consultative group on International Agricultural Research, FAO

5. Milestones and Budget:

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III, B, 7

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

7. Research Issue: Animal Agriculture

1. Significance: A CO₂-induced climate warming would impact directly on animal physiology and indirectly on forage production, soils, and animal diseases. Increases in ambient air temperatures can reduce the total productive efficiency of most livestock and increase casualty losses. This could be especially serious in some nations whose populations depend almost entirely on animals for food, fuel, and draft power.

2. Program Description: Research will focus on the effects of thermal stress on nutrient metabolism, hormones, and diseases associated with growth, reproduction, and lactation of animals and on systems of management to alleviate these effects. Environmentally controlled chambers, monitored field experiments, and other techniques will be used to examine nutrient flux and productivity in animals exposed to variable temperatures for different durations and quantitative relationships between feed intake and ambient temperatures. Studies will be conducted to determine the effects of thermal stress on the secretion and clearance rates and the release patterns and forms of hormones known to regulate growth, reproduction, and lactation. The effects of heat stress on physiological and/or biochemical factors that control fertility, embryo and fetal survival, and other aspects of reproduction will also be examined. Laboratory and field studies will be conducted to determine the effects of climatic factors on the survival, development, and movement of infectious diseases and ways to minimize disease during thermal stress. Testing will be initiated for promising management systems to alleviate thermal stress on animals, including new dietary formulations, synchronization of breeding periods with favorable conditions, and development of shelters for animals. Models will be developed to predict changes in animal productivity, compare animal production systems, simulate marketing and food consumption patterns, and determine cost/benefit ratios.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$44K</u>
Modeling Ecosystems--Climate Relationships and Participation in DOE CO ₂ Research Science Directorate	
Principal Investigator/s:	Project Number:
Cooper, Charles F.	8080
Organization/s:	Project Monitor:
San Diego State University	Dahlman, Roger C. DOE, Carbon Dioxide and Climate Division 301-353-5550

Project Summary

Task 1. Modeling Ecosystem Impacts of Climatic Change from Energy Development and Use. (Completion).

Task 2. Service on Science Directorate of DOE Carbon Dioxide and Climate Research Program. (Initiation).

Task 1 involves completion of a monograph entitled, "Modeling Ecosystem-Climate Relationships." Task 2 is to support the services of Dr. Charles F. Cooper as a member of the DOE Carbon Dioxide and Climate Research Program Science Directorate. (Research Category III: Research on the Effects of Climate Change and CO₂ Increase on the Environment.)

Category: IIIB7

III, B, 8

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

8. Research Issue: Impacts of Climate Changes on Forests

1. Significance: Shifts in climate will affect forests, grazinglands, terrestrial wildlife, water resources, and freshwater ecosystems. The relatively low level of manipulation affordable in natural systems means that there is less opportunity than in agriculture for economic benefit from climate change. The main objective of research on noncultivated ecosystems should be to anticipate responses to new climates. Research should consider the effect of climate change on recreational and aesthetic, as well as economic values. In addition, there should be a continuing program of biological monitoring to detect ecological trends. Special attention to LDCs is recommended.

2. Program Description: Research on forest ecosystems should include: development of mathematical models of forest systems; evaluation of forest species' tolerance to climate change; effects of changing climate on land-use patterns; and establishment of forest field-research sites to test ecosystem models. In the area of water resources and freshwater ecosystems, researchers should investigate: effects of temperature changes on the distribution of aquatic species; predicting and planning environmental characteristics of new reservoirs; and the impact of temperature increases on aquatic productivity. Studies of grazinglands and wildlife should examine the speed of change of ecosystem components; seeding and natural succession on abandoned croplands; variability of grazingland production; effects of climate on grazingland animals; and possible increased incidence of nomadism and desertification.

3. Priority:

4. Participating and Funding Agencies: U.S. Forest Service, Bureau of Land Management, FAO, UNEP

5. Milestones and Budget:Fiscal YearMilestonesBudget

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III, B, 9

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

9. Research Issue: Water Resources and Freshwater Ecosystems

1. Significance: Freshwater environments--streams, rivers, lakes, reservoirs, marshes, and freshwater tidal estuaries--would be affected in a variety of ways by carbon dioxide increases and associated climate changes, including higher water temperatures. Important direct impacts could include changes in aquatic productivity, species distribution, and the storage and transport of terrestrial organic matter. These could result in enhanced fish production, increased lake eutrophication, altered accessibility to fish for recreational or commercial exploitation, expansion of troublesome fish from southern regions, reductions in cold-water species in boreal lakes, and changes in the amount of carbon stored in the marine environment. Indirect impacts could be caused by new water storage reservoirs needed to maintain streamflows in watersheds where rainfall diminishes or climatic variability increases due to CO₂-induced climate changes.

2. Program Description: Careful laboratory studies of carbon dioxide enrichment, with control of other nutrients and factors such as pH, carbonate, and phosphorus, will be undertaken to quantify potential productivity increases. Field experiments involving ponds or channels will follow. Models of aquatic production will be used to elucidate the importance of limitations in carbon availability relative to other factors. Dynamic models of eutrophication will be developed to estimate the reductions in runoff due to climate changes that would induce eutrophic conditions and conversely the nutrient control requirement needed to mitigate such reductions. Laboratory and field experiments will be conducted to gather data on existing latitudinal boundaries of important aquatic species and the role of temperature in determining these boundaries. Sites near electric power stations will be examined closely, especially those where exotic species have established themselves or where native cool-water species have been eliminated. Distribution maps of aquatic species will be developed based on existing data, detailed examination of temperature's influence on various species, and continued monitoring. These studies will tap the data, resources, and talents of institutions such as museums, universities, state and local fishery agencies, and relevant federal laboratories.

In order to assess the potential indirect impacts of new reservoirs, reviews of current field research on ecological processes in reservoirs and tailwaters will be commissioned, and studies undertaken to improve predictive capabilities. Research in the U.S. will be closely coordinated with research in other nations. Data gathered to assess the effects of thermal pollution from power generation stations will be analyzed for the purpose of estimating net organic loads of rivers. Additional laboratory, field, and modeling research may be necessary, including comparative studies of aquatic systems at different

latitudes and investigation of the thermal structure of waterbodies and nonlinearities in thermal effects. New methods for determining oxidation and burial of carbon will be explored.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

III, B, 10

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

III. CO₂ Research Category: Effects of Climate Change and Carbon Dioxide Increase on the Environment

B. Research Subcategory: Effects on the Terrestrial Ecological Resources

10. Research Issue: Grazinglands and Wildlife

1. Significance: Livestock are grazed mainly on land not suitable for intensive agriculture or forestry. Such land is highly vulnerable to climatic variability. Research on the impact of climate change on grazinglands is not qualitatively different from that on agricultural and forest lands--the same processes are at work. This is true also for game and nongame wildlife.

2. Program Description: Research should investigate:

- a) Rates of change. How will the different socioeconomic systems respond to climate change? Plants should respond faster than soils, animals more slowly than plants. Lags in response could cause decreased vegetation and changes in populations of insects, changes in vegetation composition, and changes in economic and social structures.
- b) Changes in land use. Warmer temperature and less precipitation might decrease cropland areas or productivity. Forests could be converted to crops but such soils are generally less fertile. Will more fossil fuel and petro-chemicals be needed to maintain declining productivity?
- c) Seeding and succession. Should we rely on natural secondary succession on abandoned croplands, or is reseeding better? We need analysis of succession on old-field systems and consideration of seed supplies.
- d) Variability of grazingland production. What would be the variability in precipitation for the southwestern U.S., for monsoonal, Mediterranean, or oceanic zones? Economic output is related to vegetational yield. We need to examine plant and animal production due to climatic fluctuations, beginning with the most productive and/or climatically marginal grazingland types throughout the world.
- e) Grazingland animals. What livestock systems would graze newly-derived grazinglands? What would be the relationship of domestic vs. wild grazing animals, grazers vs. browsers, and cool, temperate, and tropical zone animals, to the plant communities and climatic systems that might develop?
- f) Nomadism and desertification. Climate change may exacerbate the social and biological changes caused by intensification of grazing by nomadic herders in semi-arid regions. Explicit consideration of the effects of climate change is urged.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

IV. Research Issues on Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Social and Institutional Responses

B. Economic and Geopolitical Responses

Note: For additional research supporting this issue refer to:

Title

Category

Research Plan on the Environmental and Societal
Impacts of a CO₂-Induced Climate Change

III

IV, A, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

1. Research Issue: Data Collection

1. Significance: Different kinds of data about climate change and the effects of climate change on natural systems and human societies must be made accessible to researchers from a wide variety of disciplines. Although the world inventory of weather and climate data is extensive, these have not often been reported in forms useful for predicting societal responses to climate change. The form of these data bases should be determined by collaboration among biologists, agronomists, resource managers, social scientists, climatologists, statisticians, and data processing specialists.

2. Program Description: Several different types of data bases must be compiled. An extensive data base should be compiled regarding human societies and climate change. This climate-society data bank should have a uniform, chronological set of data on change over time and the impacts of these changes on societies. Initially, the focus should be on the 13th century to the present and on Europe and North America. Additionally, crop-climate data systems should include information on regional climate and agro-resources such as soil, topography, and socioeconomic conditions. Agroclicmatic information combined with weather forecasts can be used at the farm level in selecting planting times and scheduling irrigation, fertilizer applications, and pest control measures. Biological monitoring of forests and other natural ecosystems should be undertaken on a continuing basis to identify and evaluate effects of increased carbon dioxide and climate change.

3. Priority: Climate-Society Data Bank. High

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

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IV, A, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

2. Research Issue: Impacts on Society of Past Climate Changes

1. Significance: Historical case studies are important tools for identifying and evaluating the range of likely stresses on society induced by environmental change and the possible responses to them. Interactions are so complex, and contributing factors often so varied and subtle, that a comprehensive, interdisciplinary approach is absolutely necessary.

2. Program Description: Many case studies of climate impacts have already been conducted in many different disciplines. The networking of these studies will be initiated through a systematic inventory of potential case studies, including case analogues to climate changes, a review of conceptual and methodological approaches to climate impact assessment, establishment of a coordinating body or clearinghouse to disseminate information about cases, and workshops to foster the exchange of ideas and improve the effectiveness of research. Particular attention will be given to anthropology which has extensively examined the effects on communities and households of an assortment of climatic or other stresses such as wars, epidemics, droughts, floods, and hurricanes. A uniform, chronological data bank on climatic history will be developed drawing upon the talents of historians and other scientists from many different disciplines. This data bank will focus on Europe and North America from the 13th century to the present and will include information on temperature, precipitation, length of snow cover, windiness, and the incidence of extreme climatic events such as frost, hail, floods, and drought. The data bank will be used as the basis for sorting out time scales, resolving conflicting interpretations and results, and addressing substantive questions pertaining to the effects of climate change and responses.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:Fiscal YearMilestonesBudget

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

3. Research Issue: Current Climate-Stress Surrogate Situations

1. Significance: Many events lead to environmental changes that require major adaptive responses on the part of societies. These events have some properties of climate-induced stresses and thus can be examined as climate-stress surrogates. Some examples are major seasonal droughts; prolonged very-high summer temperatures; rapidly growing boom towns in isolated, fragile environments; large-scale international migrations; environmental changes associated with chemical pollution or radiation; conditions of long-term soil erosion or exhaustion of fertility; and natural disasters with long-term environmental consequences, such as volcanic eruptions.

2. Program Description: The program should be composed of research on both current climate-stress surrogate situations and situations that occurred in the past. In current situations, teams of social scientists should enter an area for varying lengths of time to observe how families and community institutions are affected by and respond to stress situations. Researchers of past climate-change surrogates should work closely with the compilers of the climate-society data bank recommended previously.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

4. Research Issue: Societal Response Mechanisms

1. Significance: Climate changes will affect different societies, and different segments within societies, in a wide variety of ways. Agriculture, settlement patterns, demography, family structure, political institutions, and economic development are some of the aspects of society that may be impacted. The pathways and feedbacks that connect climatic factors with these societal aspects are not well understood, making predictions of future impacts due to CO₂-induced climate change difficult.

2. Program Description: Case studies, interlinked climatic and socioeconomic models, theoretical models, and other techniques will be used to identity the effects of climate variations on societies in the past and trace the pathways through which climate changes may affect specific aspects of societies. Special research teams, using the data bank developed as part of the previous research issue, will study the topics of agriculture; patterns of settlement and demography; political institutions, economic development, and social relations; and individual mentalities. New methods will be developed to link existing climate and socioeconomic models to improve estimates of the socioeconomic impacts of climate fluctuations and examination of alternative policy options. Pathways of climate impacts will be examined, especially with respect to trends over time. A workshop will be held to review past research on how environmental and other stresses affect family and social structure, evaluate its relevance for CO₂-induced climate changes, and identify contemporary situations suitable for study.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

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IV, A, 5

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

5. Research Issue: Governmental Response Mechanisms

1. Significance: Governments will clearly play a significant role in developing and implementing responses to the prospect or advent of CO₂-induced climate changes. Government actions will be needed to initiate and enforce preventive measures to reduce CO₂ emissions (e.g., by setting emission standards) or to mitigate CO₂ impacts on the climate. They may also be needed for measures to redistribute the costs and benefits of changes or to improve societal adaptability to environmental stress. Notably, the various components of governments--their executive, legislative, and judicial branches, different agencies, and so forth--will mediate responses among themselves and with individuals, households, communities, special interests, and other groups. The perceptions and actions of these components will be inextricably connected to other important policy issues. Responses involving long-range planning may be disadvantaged relative to responses to the myriad crises demanding attention in the short term.

2. Program Description: Research will be undertaken on the influence of various aspects of government organization on responses to climate changes, including study of the assignment of responsibility within government, the ability of mission agencies to cooperate with each other, the interactions and conflicts between the different branches of government, and the ability of government to plan for the long term. Ways to link CO₂-induced responses with other important policy problems will be explored. Cases of government responses to emergencies, involving, for example, the timely distribution of relief supplies to victims, will be investigated to reveal possible parallels between these cases and possible CO₂-induced situations. The impacts of governmental actions on individuals, families, communities, and other groups will be scrutinized for unintended side effects or unrealized goals.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

6. Research Issue: International System

1. Significance: A CO₂-induced climate change will affect different regions in different ways. Some regions may benefit in the net, other may suffer. This could have important implications for the international balance of economic and political power and could greatly influence national or regional willingness to cooperate and participate in preventive or adaptive measures. Climate impacts and responses to them could also aggravate existing international problems such as world hunger, unequal wealth distributions, mass migration, and conflicts over limited resources.

2. Program Description: Precise predictions of regional climate changes are not now possible with present climate models. However, extensive knowledge already exists on climate variations and extreme events, their impacts on past and present societies, and their implications for global equity. This knowledge will be reviewed and evaluated in light of potential CO₂-induced changes in the frequencies of climate variations and events. Given the inescapable uncertainties in predicting the future climate and future societal conditions, research will focus on ascertaining the likely direction of trends in climate impacts, i.e., situations in which future climatic perturbations may be handled well or in which the potential for catastrophe may be building. Relevant U.S. experience with air-quality and emission standards for pollutants, European efforts to control water pollution, and trans-boundary pollution cases such as the acid rain problem in Europe and North America will be examined. Present mechanisms for coping with shifts in economic advantage including subsidies, countervailing duties, and domestic dislocation allowances will be studied in a number of cases. The role of international diplomacy in resolving changes in international political power will be investigated.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

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IV, A, 7

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

7. Research Issue: Risk Perception, Information and Decision Making

1. Significance: Societies respond only to conditions they perceive. Consequently, a pivotal aspect of the carbon dioxide question involves how people in different cultures perceive scientific and other information and then use this information to make decisions on how to respond to the situation. In industrialized countries, many kinds of experts will provide information on climate changes, and policymakers at all levels of society will decide how to act on that information. The problem of perception raises several provocative and researchable questions in social psychology. How reliable are the judgments of experts and decision makers? What kinds of information does the public need in order to comprehend the knowns and unknowns?

2. Program Description: Research should attempt to understand and identify ways to improve nontechnical policymakers' perceptions of the facts of CO₂-induced climate change. Research should also be done on the nature and quality of expert judgment in assessing the facts about CO₂-related issues; how the public evaluates various options regarding CO₂-induced climate change; and on how climate research can be fed back effectively into policymaking bodies. Participating disciplines should include psychology, political science, sociology, economics, philosophy, and history.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:Fiscal YearMilestonesBudget

180

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IV, A, 8

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

A. Research Subcategory: Social and Institutional Responses

8. Research Issue: Effects on Human Health

1. Significance: The effect of increased atmospheric CO₂ levels and the resultant climate change will influence conditions of health and disease. The greatest impacts will be upon nutrition, insect-transmitted and other transmittable diseases, water for sanitation and hygiene, migration and stress, and health-related technological effects of trying to counter biological developments. Direct effects of lifetime exposure to elevated CO₂ are possible, but unknown at present. The severity and extent of all such impacts depend upon the nature of the climate change.

2. Program Description: A project is needed to gather and cross-reference existing health-related bioclimatic data with the aim of illuminating the interrelations of climatic, disease, and cultural patterns. Data should also be collected to identify marginal areas where climate changes could be detected first and where effects on human health would be most severe. Finally, a series of workshops should do the following: collate and map existing knowledge on climatically-controlled disease ecology; identify adaptive and maladaptive cultural behavior related to disease patterns; and construct scenarios of future patterns of migration in response to CO₂-induced climate changes.

3. Priority:

4. Participating and Funding Agencies: U.S. Public Health Service, WHO

5. Milestones and Budget:Fiscal YearMilestonesBudget

Carbon Dioxide Project Report

Project Title: Funding: FY 80 \$14K

Determination of the Carbon Dioxide
Effects on Mammalian Organisms

Principal Investigator/s:

Project Number:

Shilling, C. W., M.D.

8311

Organization/s:

Project Monitor:

Undersea Medical Society, Inc.

Blair, Joseph R.
DOE, Human Health and
Assessments Division
301-353-3269

Project Summary

Purpose: To determine the effects on human beings of low levels of chronic exposure to CO₂.

Approach: From the library and tematrex records of the Undersea Medical Society, the literature dealing with CO₂ will be retrieved, studied, and prepared for committee review. Other sources will be searched. The search will be for low level (0.3%-1.0%), long term or chronic exposure. A small committee of experts in the field will be brought together, and will assist in interpreting the literature and identifying the important findings. A report will be prepared that summarizes the important findings.

Category: IVA8

IV, B, 1

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

B. Research Subcategory: Economic and Geopolitical Consequences

1. Research Issue: Scenario Analysis

1. Significance: Because of important feedbacks among atmospheric and ocean dynamics, marine and land biota, and agriculture and energy use, the CO₂ situation can best be defined by constructing integrated scenarios. Scenarios provide a framework for integration and coordination of disparate studies and thus focus attention on the entire CO₂ picture. This can help determine whether pieces of the overall are missing, the kinds of information a product must produce in order for its research results to be useful to other studies, the timing of research outputs to ensure that results will be available when needed, and important "feedbacks" among different research areas.

2. Program Description: Several integrated scenarios should be constructed defining interesting and plausible combinations of assumptions about climate, ocean dynamics, marine biota, land biota, and agriculture, and their social implications. The scenario building should be conducted in an exercise bringing together scientists with backgrounds in climatology, oceanography, marine biology, land biology, agronomy, economics, sociology and anthropology, social psychology, and political science.

3. Priority: Emphasis should be placed on unfortunate or pessimistic scenarios, since a primary objective of social planning is guarding against disaster. High

Refine economic models of resource depletion for use in CO₂ scenario-building exercise. Medium

4. Participating and Funding Agencies:

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1981	Complete several integrated scenarios, using two assumed time paths of CO ₂ emissions.	Would require approximately one month full time from eight or nine participants, with 5-10 days input from as many as 15 additional consultants.

184

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IV, B, 2

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

B. Research Subcategory: Economic and Geopolitical Consequences

2. Research Issue: Economic Aspects of Scenarios

1. Significance: Scenario analysis will involve projections of the effects of climate changes on agricultural yield, energy required for space conditioning, changes in consumption patterns, and other economic factors. Scenario outputs will include economic measures of the social valuation and desirability of alternative policies and scenarios.
2. Program Description: Existing economic methods and models for projecting, evaluating, and presenting economic trends and data will be reviewed and applied in the generation of scenarios.
3. Priority:
4. Participating and Funding Agencies:
5. Milestones and Budget:

Fiscal YearMilestonesBudget

186

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IV, B, 3

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

B. Research Subcategory: Economic and Geopolitical Consequences

3. Research Issue: Social Aspects of Scenarios

1. Significance: A scenario is conceptually incomplete without analysis of its important implications for society. It is necessary to understand not only the implied changes in economic activity, but also the implications for individual behavior and social institutions. For example, major changes in climate and resulting alterations in agriculture and other activities might cause lifestyle changes, increased tension between various groups, and perhaps increased violence.

2. Program Description: Scenarios will identify issues that require research in depth. Particular attention will be given to unequal impacts between groups. Care will be taken so that the problem definition, units, and results all feed back into the scenarios.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

188

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IV, B, 4

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

B. Research Subcategory: Economic and Geopolitical Consequences

4. Research Issue: International Issues

1. Significance: A key aspect of the CO₂ issue is its international character. Some nations may benefit in the net from climate changes and some may lose. Some will resist abating CO₂ emissions and some will resist adaptive strategies. Short of threatening war, there is presently no way of compelling a nation to an action that it perceives to be not in its own interest. Conflicts among nations tend to be settled by negotiations or war, rather than by legal means.

2. Program Description: A theoretical examination of the implications of national self-interest with regard to the CO₂ issue will be undertaken. Particular attention will be given to the type and nature of international institutions that could encourage cooperation among nations and monitor and enforce agreements, even if not all nations were to participate voluntarily. Current international institutions will be surveyed and evaluated in light of the theoretical study in order to assess the steps needed to bring about international cooperation and action.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

Budget

190

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NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

IV. CO₂ Research Category: Social, Political, and Economic Costs and/or Benefits of Global Environmental Change

B. Research Subcategory: Economic and Geopolitical Consequences

5. Research Issue: Modeling Issues

1. Significance: Models dealing with resource depletion, decision analysis, scenario methods, social resilience, and possible mitigating strategies are critical to assessing the economic and geopolitical consequences of carbon dioxide increase and associated climate changes and actions to prevent them or mitigate their effects. Further development of such models will contribute greatly to the construction of integrated CO₂ scenarios.

2. Program Description: Existing economic models of natural-resource depletion will be reviewed and applied to the unique CO₂ situation. In particular, the Nordhaus model which has already been tailored to the CO₂ issue in preliminary fashion will be expanded and modified. The purpose of such model development will be to determine economically optimal CO₂ emission patterns and the social costs of restraining emissions. Model assumptions will also be evaluated. A decision analysis framework will be used to identify important issues and critical improvements in information for decisionmakers who must sometime in the future choose among policies regarding CO₂ emissions or adaptations to climate changes. The relevant policy choices and their likely consequences will be concisely summarized and evaluated in terms of their implications for research. A theoretical investigation of scenario methods, focusing on the CO₂ issue, will address important issues such as the uncertainties associated with model predictions, techniques to reduce them, and the influence of exogenous factors such as the future national and world economic health. Examination will also be undertaken to discover a theoretical relationship between the amount of resiliency that should be built into capital as a function of the rate of change. Given some assumptions about the amount and rate of future change and the degree of uncertainty, it should be possible to determine the optimal flexibility and resiliency of capital stock as a function of price, and thus the costs of resiliency. Mitigating strategies designed to lower costs associated with climate changes or related shocks will be examined, with particular attention on measures to ease and speed adjustment and on factors that facilitate social and economic change.

3. Priority:

4. Participating and Funding Agencies:

5. Milestones and Budget:

Fiscal Year

Milestones

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V. Research Issues on the Amelioration of Global and Sectoral Impacts

A. Preventive Measures

B. Curative Measures

C. Moderating Measures

D. Adaptive Measures

This research has not yet been developed.

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V, A-D

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

V. CO₂ Research Category: Research on the Amelioration of Global and Sectoral Impacts

A-D. Research Subcategory: Undefined at this time

Research Issues: Undefined at this time

1. Significance: If it appears that the CO₂ issue will pose significant disadvantages and costs, it may be necessary to take some positive action to reduce these costs. Two such actions are possible: (1) the reduction of CO₂ levels or reduction of rates of increase by technical fixes or fuel use strategies, or (2) the adaptation of our social, political, industrial, and agricultural systems to the new climate situation.

2. Program Description: Undefined at this time.

3. Priority: Undefined at this time.

4. Participating and Funding Agencies: DOE, with others unprojected at this time.

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1981	Workshop on Amelioration of Global and Sectoral Impacts.	
1982	Begin research program.	
1983	Continue research program and make contribution to the 1984 Interim Assessment Report.	
1984	Continue and expand research and conduct international workshop adaptation.	

6. Comments and Additional Explanations: Relatively large budgets in the later years will be required based on the assumptions that: (1) the impact of increasing CO₂ on climate will assume a greater reality as research is continued and that, (2) ameliorative actions will be found to be technically, economically, or politically unfeasible but adaptive actions will appear more appropriate.

Carbon Dioxide Project Report

Project Title:

Funding: FY 80 \$40K

Atmospheric CO₂ Control

Principal Investigator/s:

Project Number:

Albanese, A. S.

3480

Organization/s:

Project Monitor:

Brookhaven National Laboratory

Witmer, Fred E.
DOE, Environmental Control
Technology Division
301-353-5517

Project Summary

The objective of this task is to investigate and evaluate methods of controlling the concentration of CO₂ in the atmosphere resulting from fossil energy and other sources.

The approach is (1) to survey alternative environmental control technologies for application to atmospheric CO₂ control; (2) to develop conceptual process schemes for removal, recovery, and disposal of CO₂ from various sources; and (3) to assess and evaluate the control systems in terms of energy efficiency and economic costs.

The process schemes to be investigated include conventional systems and advanced systems.

The sources of CO₂ to be investigated include concentrated and diffuse sources.

The basic data and results are to be documented and made available for formulation of any possible future policy strategies.

Category: VA

VI

NATIONAL PROGRAM ON CARBON DIOXIDE, ENVIRONMENT AND SOCIETY

VI. CO₂ Research Category: CO₂ Review, Integration, and Evaluation
(Assessment) Program

1. Significance: The critical analysis of the relevant data and information in order to make confident estimates of the costs or benefits of the CO₂ issue is the central focus of the National Carbon Dioxide Effects Research and Assessment Program and is looked upon as an integral part of that Program. It is this activity that will supply the type of information upon which energy policy can be developed.

2. Program Description: The Assessment Program is being designed to perform two functions:

- a) To describe the societal costs or benefits of the CO₂ issue with sufficient confidence to permit policy decisions to be made;
- b) To review the research program to determine whether it is properly oriented toward the Program goal.

The output of the Assessment Program will be the 1984-Interim Assessment Report, the most authoritative expression of the understanding of the CO₂ issue that the national and international scientific communities can pursue.

3. Priority: This will become the highest priority undertaking in the Program by 1981-82.

4. Participating and Funding Agencies: DOE

5. Milestones and Budget:

<u>Fiscal Year</u>	<u>Milestones</u>	<u>Budget</u>
1980	Expand participation in Program.	
1981	Continue Program. Publish special assessment reports.	
1982	Major activity is the preparation of the 1984-Interim Assessment Report.	
1983	Finalization of 1984-IAR and reviews.	
1984	Publication of 1984-IAR and CO ₂ Program re-evaluation and recommendation.	

Carbon Dioxide Project Report

Project Title:	Funding: FY <u>80</u> <u>\$228K</u>
CO ₂ Assessment, Emissions, Information and Services Task I - CO ₂ Assessment	
Principal Investigator/s:	Project Number:
Rotty, Ralph M.	2932
Organization/s:	Project Monitor:
Institute for Energy Analysis/ Oak Ridge Associated Universities	Slade, David H. DOE, Carbon Dioxide and Climate Division 301-353-4374

Project Summary

Assessment: The Institute for Energy Analysis will maintain a continuous review and assessment of all aspects of the CO₂ problem, maintain full awareness of all research on CO₂, and develop a comprehensive plan to assess CO₂ effects. Experts in all aspects are being assembled. This team will provide a base to generate a definitive report in 1984, and to respond to DOE inquiries with the most current information.

| Category: VI