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Carbon Dioxide Information Analysis Center and World Data Center-A for Atmospheric Trace Gases

Catalog of Databases and Reports



Carbon
Dioxide
Information
Analysis
Center

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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**Carbon Dioxide Information Analysis Center
World Data Center—A for Atmospheric Trace Gases**

Catalog of Databases and Reports

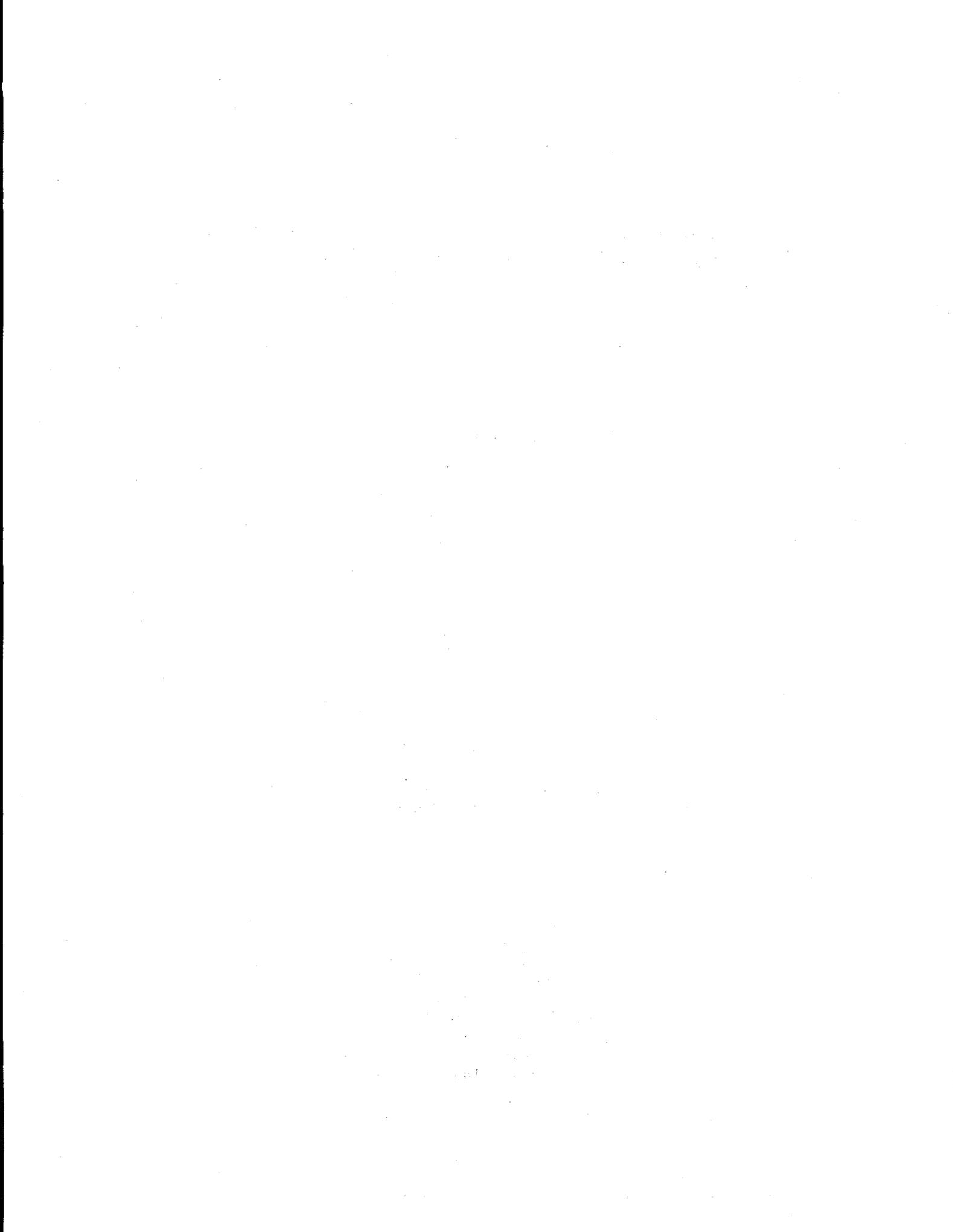
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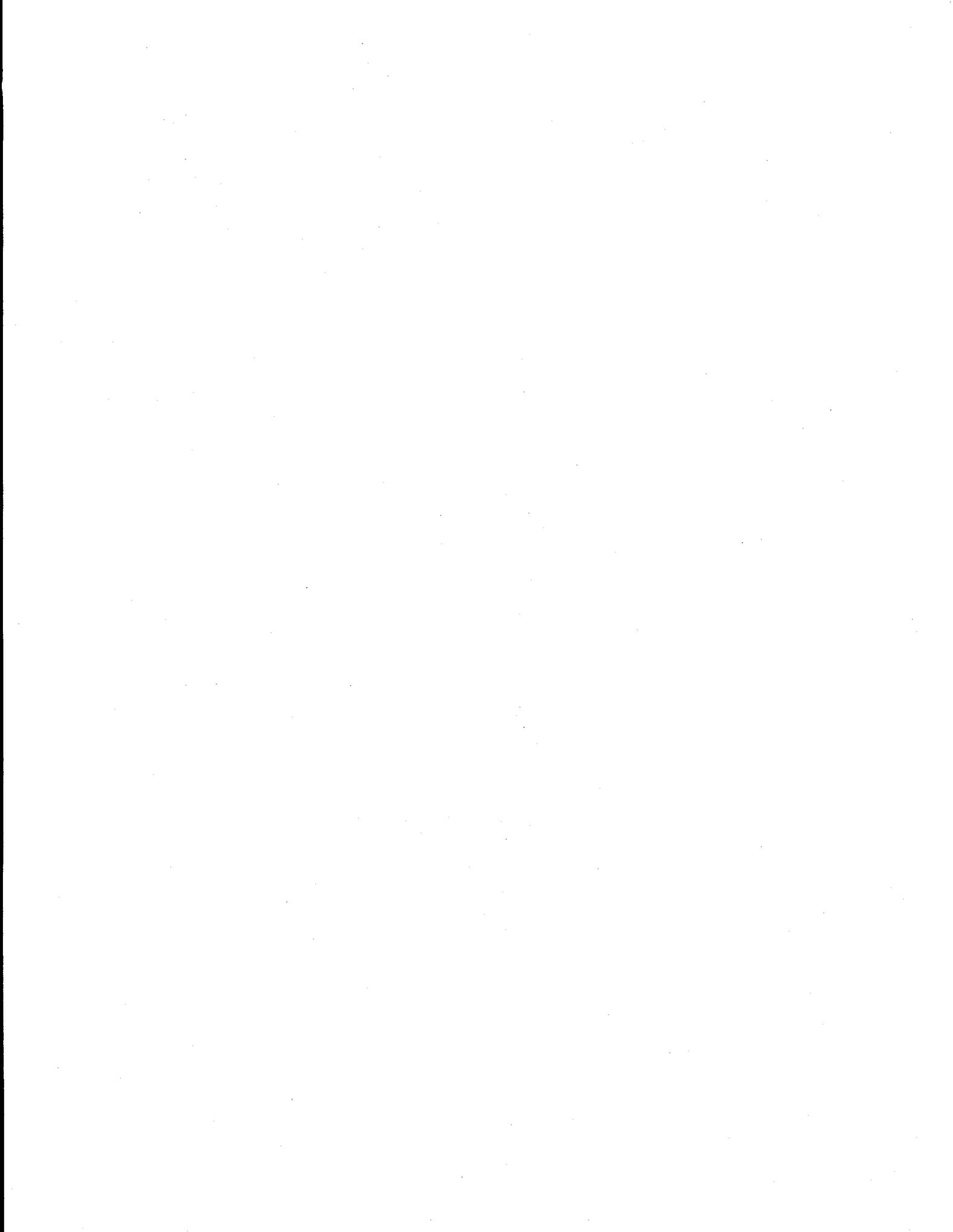
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Contents

Introduction	v
Section A—U.S. Department of Energy Global Change Research Program Research Plans and Summaries	1
Section B—U.S. Department of Energy Global Change Research Program Technical Reports	11
Section C—U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program Reports	53
Section D—Other U.S. Department of Energy Reports	59
Section E—CDIAC Reports	71
Section F—CDIAC Numeric Data and Computer Model Distribution	85
Section G—Other Data Sets Distributed by CDIAC	113
Section H—USDA Reports on Response of Vegetation to Carbon Dioxide	123
Section I—Other Publications	127
Author Index	137
Title Index	177
Accessing CDIAC's Anonymous FTP Area	201



Introduction

This document, *Catalog of Databases and Reports*, provides information about the many reports and other materials made available by the U.S. Department of Energy's (DOE's) Global Change Research Program (GCRP). It is divided into nine sections plus author and title indexes:

Section A—U.S. Department of Energy Global Change Research Program Research Plans and Summaries

Section B—U.S. Department of Energy Global Change Research Program Technical Reports

Section C—U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program Reports

Section D—Other U.S. Department of Energy Reports

Section E—CDIAC Reports

Section F—CDIAC Numeric Data and Computer Model Distribution

Section G—Other Data Sets Distributed by CDIAC

Section H—USDA Reports on Response of Vegetation to Carbon Dioxide

Section I—Other Publications

The reports in Sect. A provide information about the scope, activities, and direction of the GCRP. Sections B, C, D, and E contain information about research that has been sponsored by GCRP, including those produced by CDIAC.

The numeric data packages (NDPs) and computer model packages (CMPs) (described in Sect. F) have been compiled by GCRP's Carbon Dioxide Information Analysis Center (CDIAC). NDPs and CMPs include documents and transfer media [i.e., 9-track magnetic tape(s), IBM-formatted floppy diskettes, or CD-ROM]. The data may also be obtained by accessing CDIAC's anonymous FTP area (see p. 193 for instructions on how to access the anonymous FTP area). The documentation provides complete descriptions of the data set, describes limitations and restrictions of the data, suggests data applications, provides tabular listings and graphical displays of the data, and includes reprints of pertinent literature. The transfer media provide machine-readable data files, FORTRAN and SAS retrieval codes to read and print the data files, and descriptive files that explain the contents and format of each data file. Section G describes additional data bases distributed by CDIAC.

Section H describes reports about research in the joint program of the U.S. Department of Agriculture and GCRP, and Sect. I contains reports from various workshops, symposia, and reviews.

CDIAC operates the World Data Center—A (WDC-A) for Atmospheric Trace Gases, a component of the World Data Center System coordinated by the International Council of Scientific Unions. CDIAC publications that are also WDC-A reports are denoted by (WDC-A) beneath the publication number.

Reports and materials listed herein are distributed free of charge by CDIAC while supplies last. Documents in Sects. A, B, C, D, and F (document only, no magnetic media) can also be purchased from the National Technical Information Service or DOE's Office of Scientific and Technical Information.

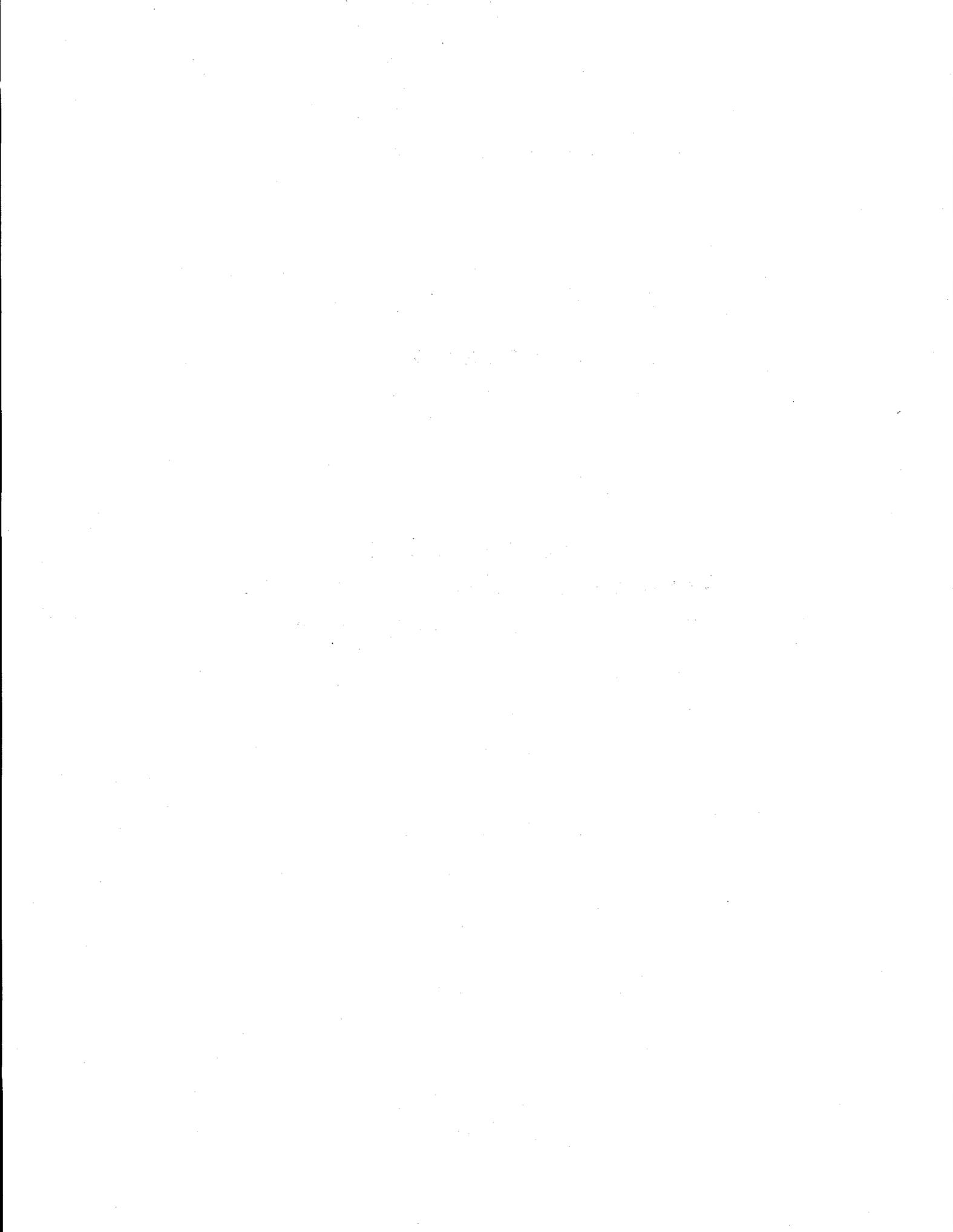
Other materials and services are available, including a semiannual newsletter, *CDIAC Communications*, which provides information about current global change research, CDIAC services, and new publications and upcoming meetings related to global change.

To request any of the materials listed in this booklet call or write:

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Section A

U.S. Department of Energy Global Change Research Program Research Plans and Summaries



The Carbon Dioxide Research Plan: A Summary**(November 1983)****DOE/ER-
0178****Carbon Dioxide Research Division, U.S. Department of Energy**

The purpose of this plan is to provide all present and potential participants in evaluating the carbon dioxide issue with a clear picture of the current scope and activities of the Department of Energy's Carbon Dioxide Research Program and the direction it is likely to take in the near future. The plan summarizes the goals, objectives, and approaches used in research on the carbon cycle, climate and first detection, vegetation responses, and indirect effects.

CO₂ Climate Research Plan**(December 1983)****DOE/ER-
0186****M. R. Riches, Carbon Dioxide Research Division**

This research plan, which is part of the U.S. Department of Energy's Carbon Dioxide Research Program, addresses the questions related to the global and regional rate of CO₂-induced climate change. The objective of the plan is to define the key questions in such a way that research is directed at experiments where answers are needed, rather than at experiments where answers can be easily obtained.

Vegetation Response to Carbon Dioxide Research Plan**(January 1984)****DOE/ER-
0187****R. C. Dahlman, Carbon Dioxide Research Division**

This report summarizes the U.S. Department of Energy Carbon Dioxide Research Program's research plan on vegetation response to carbon dioxide. The plan includes a short history of the effects of CO₂ on vegetation followed by a description of the structure of the vegetation response system. The main part of the plan describes the research tasks within the system, and the final section summarizes the program priorities and scheduling.

Carbon Cycle Research Plan**(January 1984)****DOE/ER-
0188****R. C. Dahlman, Carbon Dioxide Research Division**

This report summarizes the carbon cycle research plan of the Carbon Dioxide Research Program of the U.S. Department of Energy. It includes a short history of atmospheric CO₂ levels and what is known about global carbon cycle exchanges. The main part of the plan describes the research tasks and the relationship and priorities of the components.

**DOE/ER-
0202**

**Carbon Dioxide and Climate: Summaries of Research in
FY 1983 and FY 1984**
(September 1984)

Carbon Dioxide Research Division, U.S. Department of Energy

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Years 1983 and 1984. It includes descriptions of all projects funded annually in these years or under multiple year contracts from Fiscal Year 1982. Also, a brief summary of the Program's goals, objectives, and organization is provided.

**DOE/ER-
0202/1**

**Carbon Dioxide and Climate: Summaries of Research in
FY 1985**
(September 1985)

Carbon Dioxide Research Division, U.S. Department of Energy

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1985. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

**DOE/ER-
0299**

**Carbon Dioxide and Climate: Summaries of Research in
FY 1986**
(October 1986)

Carbon Dioxide Research Division, U.S. Department of Energy

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1986. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

**DOE/ER-
0347**

**Carbon Dioxide and Climate: Summaries of Research in
FY 1987**
(October 1987)

Carbon Dioxide Research Division, U.S. Department of Energy

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1987. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

Carbon Dioxide and Climate: Summaries of Research in FY 1988
(October 1988)DOE/ER-
0385**Carbon Dioxide Research Division, U.S. Department of Energy**

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1988. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

Carbon Dioxide and Climate: Summaries of Research in FY 1989
(October 1989)DOE/ER-
0425**Carbon Dioxide Research Program, U.S. Department of Energy**

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1989. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

Carbon Dioxide and Climate: Summaries of Research in FY 1990
(October 1990)DOE/ER-
0470T**Carbon Dioxide Research Program, U.S. Department of Energy**

This Program Summary documents the activities and products of the Carbon Dioxide Research Program in Fiscal Year 1990. It includes descriptions of all projects funded and a brief summary of the CDR Program's goals, objectives, and organization.

Carbon Dioxide and Climate: Summaries of Research in FY 1991
(October 1991)DOE/ER-
0508T**Carbon Dioxide Research Program, U.S. Department of Energy**

This Program Summary describes the activities and products of the Carbon Dioxide Research Program in FY 1991. It includes descriptions of all projects funded and a brief summary of the CDR program's goals, objectives, and organization.

**Multi-Year Strategic Plan for the Atmospheric Studies in
Complex Terrain (ASCOT) Program**
(June 1992)DOE/ER-
0549T**Environmental Sciences Division, U.S. Department of Energy**

The effects of topographical forcing on the atmosphere's planetary boundary layer encompass a broad range of phenomena, an understanding of which is essential for a variety of theoretical and

practical applications in the atmospheric sciences. In particular, the transport and diffusion of airborne pollutants in regions of complex terrain are strongly affected by the properties of the boundary layer. The ability to describe and predict the fate of airborne contaminants, from either routine or accidental releases, is a crucial issue in air quality and emergency preparedness and response studies. In many instances, however, the relevant boundary layer processes have not yet been well-characterized, let alone understood. The effects on boundary layer properties arising from inhomogeneous surface fluxes of heat and moisture into the atmosphere over mountainous regions have received relatively little attention but are expected to be significant. Such effects, as well as the interactions of local and regional atmospheric circulations with large scales of flow, are a central problem in the development of regional- and global-scale computational models used to predict climate change and its possible effects on smaller scales.

The U.S. Department of Energy's (DOE) Atmospheric Studies in Complex Terrain (ASCOT) program addresses these issues through an integrated program of measurements, modeling and analysis. Specifically, ASCOT is a basic research program studying the properties of atmospheric boundary layers over nonuniform terrain and the interactions among various scales of motion that influence those properties. ASCOT has two principal goals: (1) to characterize, understand, and predict boundary layer structure and evolution over inhomogeneous terrain, with scales of motion of order 1 km to 100 km, and (2) to develop methodologies needed to apply this knowledge to DOE mission needs, both site-specific and generic, including site safety, air quality, and climate change.

The current foci of ASCOT activities are the Tennessee Valley, particularly near Oak Ridge National Laboratory and the Front Range of the Colorado Rocky Mountains in the vicinity of DOE's Rocky Flats Plant. The first site is a broad valley between two mountain chains, whereas the second forms the interface between a large mountain range and an adjacent plain. Both sites develop boundary layers whose properties are strongly affected by local terrain features as well as by larger-scale terrain and synoptic influences. Within these areas, ASCOT's objectives are to characterize and analyze the structure of the planetary boundary layer and its principal thermally driven circulations on scales on the order 1 to 100 km and to develop, test, and validate models describing the resultant transport and diffusion of atmospheric pollutants that may be released there. Technological advances developed through this research will be made available to scientists at the two DOE sites. As the ASCOT program acquires additional instrumentation, particularly remote-sensing profilers for measuring winds and temperatures aloft, it will include more detailed studies of the properties of the boundary layer over mountains themselves. These objectives are closely aligned not only with mission requirements of DOE but also with initiatives of the National Energy Strategy.

**DOE/ER-
0565T**

**Global Change Research: Summaries of Research in FY 1992
(October 1992)**

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Global Change Research Program in FY 1992. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

**Atmospheric Sciences Program Summaries of Research in
FY 1992**
(November 1992)

**DOE/ER-
0568T**

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Atmospheric Science Program of the Environmental Sciences Division, Office of Health and Environmental Research, Office of Energy Research, in FY 1992. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

**Overview of the DOE Atmospheric Chemistry Program's Ozone
Project**
(January 1993)

**DOE/ER-
0575T**

Environmental Sciences Division, U.S. Department of Energy

This document, which describes the background and initial design for the DOE Ozone Project, defines initial DOE plans.

Atmospheric Chemistry Program. Program Operation Plan
(April 1993)

**DOE/ER-
0586T**

Environmental Sciences Division, U.S. Department of Energy

The Department of Energy's Atmospheric Chemistry Program (ACP) was initiated in 1991 to coordinate DOE's university and federal-laboratory atmospheric-chemistry research and to focus these efforts on national and international information requirements in the atmospheric-chemistry field.

This Program Operations Plan describes the structure and vision of the effort designed to fulfill these needs, and is divided into two major components. The first of these is a Strategic Plan, which outlines the ACP's rationale, objectives, and vision and describes the products that are anticipated over a future 10-year period.

The second component of the Program Operations Plan, the Implementation Plan, deals directly with resource considerations. As such, it focuses on practical implementation of Strategic-Plan elements at the individual research institutions, the anticipated scientific contributions of these groups, and their coordination within the ACP. In contrast to the Strategic Plan, the Implementation Plan extends only 5 years into the future.

**DOE/ER-
0596T**

**Atmospheric Sciences Program. Summaries of Research
in FY 1993**
(November 1993)

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Atmospheric Sciences Program of the Environmental Sciences Division, Office of Health and Environmental Research, Office of Energy Research, in FY 1993. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

**DOE/ER-
0597T**

Global Change Research: Summaries of Research in FY 1993
(October 1993)

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Global Change Research Program in FY 1993. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

**DOE/ER-
0641T**

Global Change Research: Summaries of Research in FY 1994
(April 1995)

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Global Change Research Program in FY 1994. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

**DOE/ER-
0650T**

**Atmospheric Sciences Program. Summaries of Research
in FY 1994**
(June 1995)

Environmental Sciences Division, U.S. Department of Energy

This document describes the activities and products of the Atmospheric Sciences Program of the Environmental Sciences Division, Office of Health and Environmental Research, Office of Energy Research, in FY 1994. It includes descriptions of all projects funded and a brief summary of the program's goals, objectives, and organization.

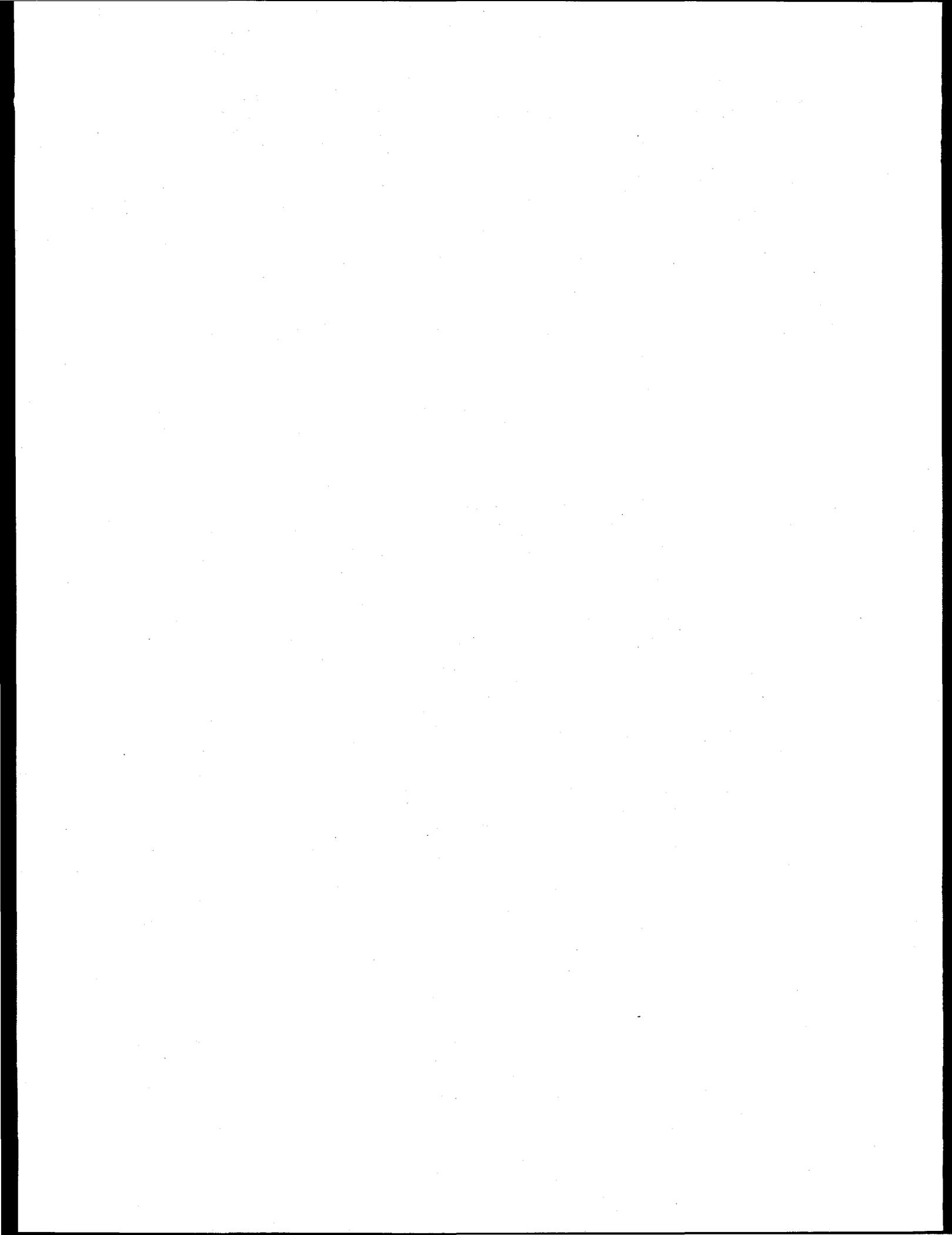
**Natural and Accelerated Bioremediation Research (NABIR)
Program Plan
(September 1995)****DOE/ER-
0659T****Office of Energy Research, U.S. Department of Energy**

This draft plan describes a 10 year program to develop the scientific understanding needed to harness and develop natural and enhanced biogeochemical processes to bioremediate contaminated soils, sediments and groundwater at DOE facilities. The Office of Health and Environmental Research (OHER) developed this program plan, with advice and assistance from the DOE Office of Environmental Management (EM). The program builds on the OHER tradition of sponsoring fundamental research in the life and environmental sciences and was motivated by OHER's and Office of Energy Research's (OER's) commitment to supporting DOE's environmental management mission and the belief that bioremediation is an important part of the solution to DOE's environmental problems.

**Elements of Change 1994. Climate-Radiation Feedbacks: The
Current State of the Science
(July 1994)****DOE/ER-
0661T****Environmental Sciences Division, U.S. Department of Energy**

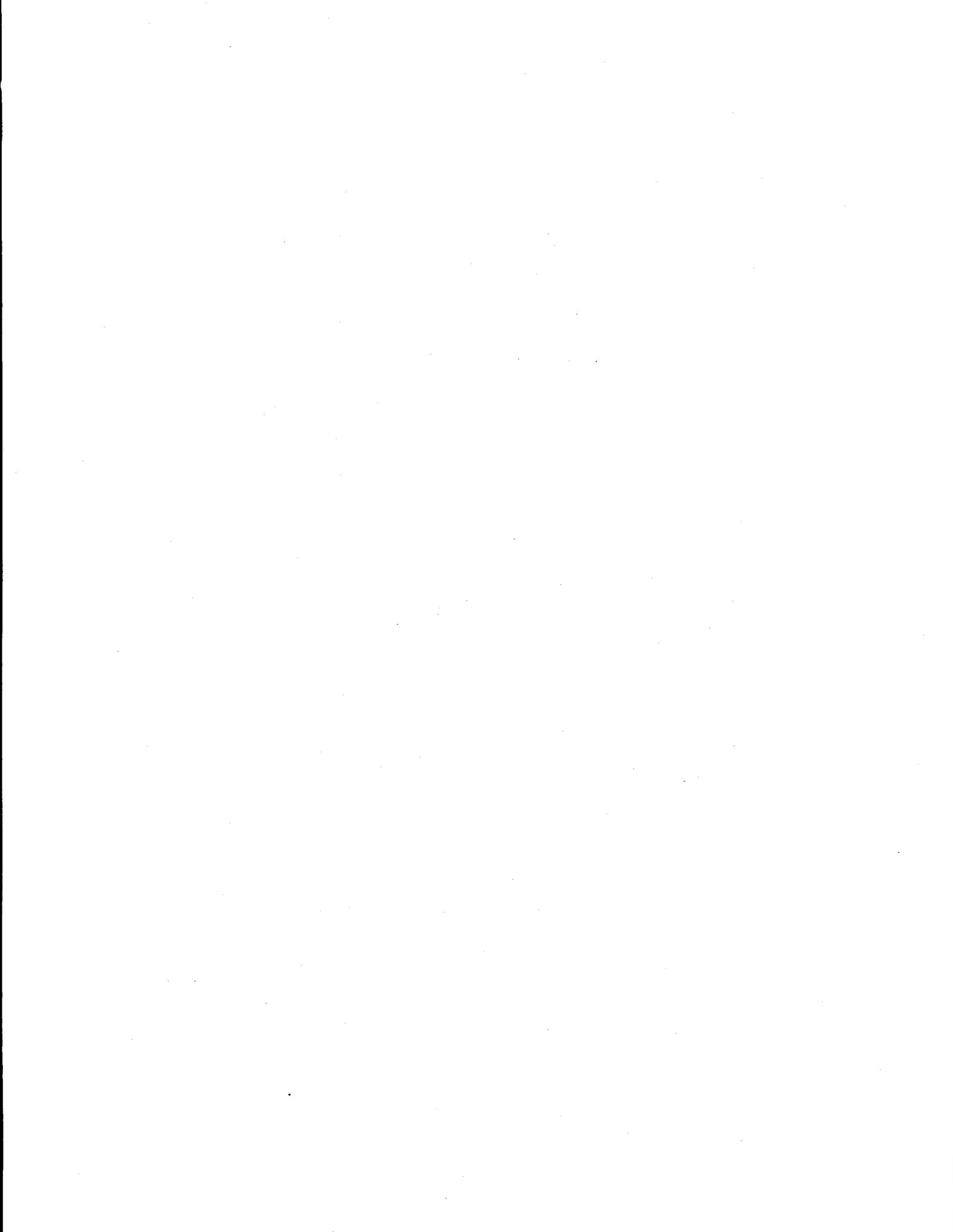
The Aspen Global Change Institute (AGCI) devoted its first of three 1994 summer science sessions to the topic of climate-radiation feedbacks and the credibility of atmospheric models. Twenty-five scientists participated, including three graduate students, a few young postdoctoral researchers, and a preponderance of senior people.

The topic was picked because of its scientific importance and timeliness. Cloud-radiation interactions have long ranked as one of the most critical areas in global change research. In particular, when climate models are intercompared, cloud-radiation parameterizations are responsible for most of the global-mean differences in sensitivity to greenhouse gas increases. The uncertainty in model response is a direct result of a lack of fundamental understanding of the physical processes involved. A major research effort is underway worldwide in response to this challenge. One prominent example is the Atmospheric Radiation Measurement Program, the flagship global change effort of the U.S. Department of Energy, which has been undertaken in response to this pressing scientific need.



Section B

U.S. Department of Energy Global Change Research Program Technical Reports



On Possible Changes in Global Sea Level and Their Potential Causes
(DOE/NBB-0022, November 1982, 49 pp.)

TR001

T. P. Barnett, Scripps Institution of Oceanography

The purpose of this paper is to review the behavior of global sea level over the last century. This analysis of global sea level avoids the space and time bias of previous works. Between 1903–1969, a coherent pattern of increasing relative sea level (RSL) was found to exist on average at all stations analyzed. Subject to numerous assumptions, RSL increase associated with this pattern was 15 cm/century. A similar analysis of the period 1930–1975 again showed RSL increasing everywhere except in the western half of the North Pacific Ocean in which a decrease was found. This decrease in RSL is substantiated further by hydrographic data. Thus, in recent years, the concept of a global sea level rise is not supported. The temporal behavior of the near global signals from both time periods was approximated well by a simple linear trend. There was no evidence of a more rapid rise in RSL in recent years.

In this analysis, potential causes of the above RSL change were investigated. Changes in the position of the earth's axis of rotation support the idea that the RSL change was caused by approximately equal melting of Greenland/Antarctica ice. Changes in the length of day only marginally support this idea. However, other attractive geophysical explanations for variations in both these astronomical parameters exist. Observed change in sea surface temperature (SST), if representative of reasonable changes in vertical thermal structure, could give the observed RSL change. However, the SST data are likely biased instrumentally toward an increasing trend. Also, thermal expansion of the oceans would not significantly affect the rotational parameters although changes in these parameters could be the result of non-RSL related processes. Changes in ocean circulation and subsidence along all the coastal margins seem unlikely causes of the observed change in RSL. In summary, it is not possible at this time to explain reliably the apparent increase in RSL.

Effects of Approximate Radiation Treatments Used in the Climate Models on the Clear Sky Thermal Radiation Flux and Its Perturbation Due to CO₂ Increase

TR002

(DOE/ER/60023-1, January 1983, 41 pp.)

W-C. Wang, Atmospheric and Environmental Research, Inc.

This report presents an assessment of the effects of approximate radiation treatments, which are commonly adopted in climate models, on the calculated thermal radiation flux, and of the effect of the approximations on the flux's perturbation due to CO₂ increase.

In this assessment, the uncertainties in the calculated clear sky thermal flux associated with the approximations (Curtis-Godson and correlated-k methods) for inhomogeneous atmosphere, the use of exponential kernel (diffusivity factor) approximation, the treatment of model layer temperature (constant and linear Planck function), and the representation (narrow and wide band) for the correlation of spectral features between the overlapping gases and the Planck function are examined.

The results indicate that for an inhomogeneous atmosphere the correlated-k method calculates nearly identical flux and flux perturbation as those computed using the Curtis-Godson method.

The results also suggest that the use of a diffusivity factor (1.66) to represent the zenith angle integration is appropriate for CO₂ thermal radiation calculations.

However, the narrow band representation which accounts for the correlation of spectral features tends to calculate a smaller atmospheric opacity than the wide band representation which neglects such a correlation. As a result, the latter computes a much larger downward flux at surface as well as its increase due to CO₂ increase. It is also found that the calculated thermal flux is very sensitive to the treatment of model layer temperature.

TR003 Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1981
(DOE/NBB-0036, June 1983, 75 pp.)

G. Marland and R. M. Rotty, Oak Ridge Associated Universities, Institute for Energy Analysis

The purpose of this report is to provide detailed documentation for a procedure to estimate CO₂ emissions from fossil fuels and to make independent and updated estimates of the rate at which fossil fuel combustion has released carbon dioxide into the atmosphere.

With new data and revised methods, an attempt is made to reduce the uncertainties. For each type of fuel, the annual global CO₂ emissions are the product of three terms: the amount of fuel produced, the fraction of the fuel that becomes oxidized, and a factor for the carbon content of the fuel.

An important outcome of this independent examination of the full computation of CO₂ emissions from fossil fuels is that no fundamental oversights in the earlier methods of Keeling and of Rotty were discovered. An additional result of this examination is estimates of the uncertainties in the final numbers. The largest absolute uncertainty enters the computation with the United Nations data set for fuel production but even here global fuel production is dominated by a small number of countries, most of which are believed to maintain and publish good statistical records. Although the estimated uncertainty in the CO₂ emissions is about 10 percent, the trend of increasing emissions from fossil fuels is firmly established.

TR004 Carbon in Live Vegetation of Major World Ecosystems
(DOE/NBB-0037, June 1983, 152 pp.)

J. S. Olson, J. A. Watts, and L. J. Allison, Oak Ridge National Laboratory

The objectives of this research were to make a computer generated world map of vegetation and carbon density for natural and modified ecosystem complexes and to illustrate some human influences on the global carbon cycle. A data base was compiled to make a seven color ecology map (1:30,000,000 near the equator) of 44 land ecosystem mosaics or subdivisions in seven broad groups: Forest and Woodland; Interrupted Woods; Mainly Cropped, Residential, Commercial, and Park; Grass and Shrub Complexes; Tundra and Desert; Major Wetlands; and Other Coastal, Aquatic, and Miscellaneous.

The map provides a basis for making improved estimates of vegetation areas and carbon quantities, natural biological exchanges of CO₂, and net historic shifts of carbon between the biosphere and the atmosphere. It is derived from the patterns of preagricultural vegetation or potential vegetation types and their relation to carbon content and from modern aerial surveys and intensive biomass data from

research sites. Ecosystem complexes are defined and located (with a $0.5^\circ \times 0.5^\circ$ grid) to reflect the major climatic, topographic, and land-use patterns.

Estimates of biomass in trees and total carbon in live plants per unit are tabulated. The results help define the role of the terrestrial biosphere in the global carbon cycle. Results also imply major historic reductions of global carbon for broad regions and most vegetation types. Lowered estimates of carbon caused by forest harvest or clearing for crops in the last century imply lowered estimates of input of nonfossil CO_2 to the atmosphere. The map of Major World Ecosystem Complexes indicates where some of the recent and future changes of organic carbon are most likely: in tree formations and wetlands where wood or peat reserves are still high in some of the interrupted woods where recent land-use transition rates have been high. Refinement and use of the map and its associated data bases continue in research, for example, on flux estimates for fire, forest clearing, and other carbon exchanges in models of the global carbon cycle.

Deforestation Measured by LANDSAT: Steps Toward a Method
(DOE/EV/10468-1, June 1983, 62 pp.)

TR005

G. M. Woodwell, J. E. Hobbie, R. A. Houghton, J. M. Melillo, B. J. Peterson, G. R. Shaver,
and T. A. Stone, The Ecosystems Center, Marine Biological Laboratory

B. Moore, Complex Systems Research Center, University of New Hampshire

A. B. Park, The Space Systems Division, General Electric Company

The increase in atmospheric CO_2 over the past century is due in part to deforestation. The LANDSAT system appears to have the potential for providing objective, synoptic and repetitive information on rates of clearing of forests globally. The purpose of this work was development of a method for using the LANDSAT system to determine net change in the area of forests, and therefore in the amount of carbon held in terrestrial systems, globally. Three approaches to the use of LANDSAT data for this purpose seemed possible. First, if a sufficiently detailed classification of a vegetation can be made from a single LANDSAT image, an estimate of net flux is possible through use of the model. This is the single image approach. Second, LANDSAT imagery might be used to construct two classification inventories of the amount of carbon in the vegetation at different dates. Finally, the technique of change detection using satellite imagery might be applied by subtracting the digital information in a later image from a former image to produce a third data set that records only the changes. It is, of course, these changes that are the objective.

The change detection method holds the greatest promise because it reduces the problems of misclassification evident in the single and double inventory methods. The method was simplified further by establishing the criteria of change as two gross changes, that from forest to non-forest, and that from non-forest to forest. The problems of classification of imagery have thereby been reduced to little more than detection.

A system of sampling was suggested for a global survey. Sampling would be stratified to favor areas where changes are abundant. Thirty-nine countries or states within countries account for 90% of published estimates of deforestation in the tropics and subtropics. To cover these countries once by LANDSAT requires about 1,200 scenes. Further stratification within countries can be based on zones or fronts of intense deforestation. LANDSAT imagery required to cover these zones is about 500 scenes. Since current estimates of deforestation in the tropics may vary by 600%, a reduction of the uncertainty to $\pm 10\%$ may be a greater improvement than is

appropriate. If an uncertainty of +/- 25% were acceptable, the required sample for the important tropical countries and for the fronts of deforestation would be 360 and 75 scenes, respectively. The cost of a five year program designed to reduce the uncertainty to +/- 25% was estimated as 4 to 7 million dollars for data and imagery analysis.

TR006 Response of the North American Corn Belt to Climate Warming
(DOE/NBB-0040, August 1983, 27 pp.)

T. J. Blasing and A. M. Solomon, Oak Ridge National Laboratory

This report explains the projections of the influence of a climatic change on the location of the North American corn belt. The climate of this corn belt was characterized to estimate the effects of climatic change on that agricultural region. Heat and moisture characteristics of the current corn belt were identified and mapped based on a simulated climate for a doubling of atmospheric CO₂ concentrations. The result was a map of the projected corn belt corresponding to the simulated climatic change. Such projections were made with and without an allowance for earlier planting dates that could occur under a CO₂-induced climatic warming. Because the direct effects of CO₂ increases on plants, improvements in farm technology, and plant breeding are not considered, the resulting projections represent an extreme or "worst" case.

The results indicate that even for such a "worst" case, climatic conditions favoring corn production would not extend very far into Canada. Climatic "buffering" effects of the Great Lakes would apparently retard northeastward shifts in corn-belt location.

Changes in timing of annual climatological events are important to crop responses, but little is currently known about these phenomena. Timing is thus a major source of uncertainty in specifying agricultural responses to climatic change.

TR007 An Analysis of Concepts for Controlling Atmospheric Carbon Dioxide
(DOE/CH/00016-1, December 1983, 66 pp.)

M. Steinberg, Brookhaven National Laboratory

This report reviews and analyzes possible mitigating technologies and processes for the control of the CO₂ effect. This analysis addresses the mitigation of the CO₂ effect mainly by controlling the CO₂ content in the atmosphere. As such, the steps involve either restriction of emission, or the removal, recovery, disposal, and reuse of CO₂.

TR008 Carbonate Chemistry of the Weddell Sea
(DOE/EV/10611-4, March 1984, 118 pp.)

C.-T. A. Chen, Oregon State University

Concurrent pH, calcium, and total alkalinity data were obtained in the eastern Weddell Sea during the winter of 1981. These data represent the initial concentrations of calcium, alkalinity, and total CO₂ in the most important source region of world ocean bottom waters at the time they were formed. For the first time, an evaluation of the variation of calcium and carbon cycles in the deep oceans referenced to the source water were made. The data were analyzed together with data from the literature, and the

results indicated that: (1) the October pH values south of the Polar Front are indistinguishable from the November values, but the seasonal effect is large north of the front; (2) a large change in pH occurs at the ice edge; (3) partial pressure of CO₂ in the Weddell Sea surface water is only slightly lower than the atmospheric value; (4) alkalinity does not show cross-ice- edge or seasonal variations, but the values seem to increase at a slower rate with decreasing temperature south of the Polar Front; (5) sea ice is relatively high in calcium and alkalinity concentrations; (6) mixing dominates the distribution of chemical properties; (7) pH is useful in identifying the sources of waters in the Weddell Sea, whereas calcium and alkalinity are not; (8) the surface water is deficient in CO₂ from human activities because the pack ice blocks the air-sea exchange of gases; and (9) little excess CO₂ can be found in the Antarctic Bottom Water. The situation may change, however, if the Weddell Sea ice coverage is reduced because of CO₂-induced global warming.

[The data set is available on tape (NDP-028) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

**Response of Unmanaged Forests to CO₂-Induced Climate Change:
Available Information, Initial Tests, and Data Requirements**
(DOE/NBB-0053, April 1984, 93 pp.)

TR009

A. M. Solomon, M. L. Tharp, D. C. West, G. E. Taylor, J. W. Webb, and J. L. Trimble,
Oak Ridge National Laboratory

In this report, the scientific literature is reviewed to determine how tree recruitment, growth, and mortality are related to climate directly and indirectly through climate's modulation of plant competition, succession, and migration. The resulting potential responses of forest communities to climate changes expected under increased atmospheric CO₂ concentrations are described.

Empirical data sets, containing measurements of climate variables and tree densities in the eastern United States, are evaluated for their potential use in statistical projections of forest responses to climate change. Also evaluated for projection purposes is a forest-stand simulation model based on many of the processes that determine forest dynamics. The ability of the model to reproduce extant forests at 21 sites in eastern North America was first verified. Then, a model experiment simulated responses of forests at those 21 locations to a scenario in which climate responds to doubling and quadrupling of CO₂. The implications of the forest simulations are discussed in terms of internal forest dynamics and requirements for specified information from climate projections, as well as for additional model developments that could address remaining ecological uncertainties.

**Computer Implementation of a Globally Averaged Model of the World
Carbon Cycle**
(DOE/NBB-0062, July 1984, 79 pp.)

TR010

W. R. Emanuel, G. G. Killough, W. M. Post, and H. H. Shugart, Oak Ridge National Laboratory

M. P. Stevenson, Science Applications, Inc.

A model of the global carbon cycle and its computer implementation are described in this report. Three major components of the cycle—the atmosphere, oceans, and terrestrial ecosystems—are represented. The dynamics of total carbon (i.e., mass of ¹²C + ¹³C and ¹⁴C), and the two less

abundant isotopes, ^{13}C and ^{14}C , are treated. The model equations are derived from a compartment diagram of the cycle by expressing mass balance for each compartment as a first-order differential equation. The atmosphere is represented by a single compartment and the oceans by 19 globally-averaged layers with depth. Carbon in terrestrial ecosystems is divided among five compartments. The model simulates phenomena on time scales from several years to several centuries. Carbon dioxide released to the atmosphere by fossil fuel combustion and ^{14}C produced naturally in the atmosphere or by nuclear weapons tests are incorporated as exogenous inputs. Forest clearing results in a direct transfer of carbon to the atmosphere to "trees" and "ground vegetation" are altered as a result of land-use change.

The model is implemented in FORTRAN. Readily available routines are used for standard numerical procedures. The model does not access exogenous data sets; parameter values and control variables are set in data initialization statements. Tabulated results are provided as printed output.

TR011 Historical Carbon Dioxide: Abundances Derived from the Smithsonian Spectrobolograms
(DOE/NBB-0063, August 1984, 114 pp.)

G. M. Stokes, J. C. Barnard, and E. W. Pearson, Pacific Northwest Laboratory

This report describes results of the analysis of the Smithsonian Solar Constant Program spectroscopic data to determine atmospheric CO_2 concentrations before 1958. A representative sample of Smithsonian Spectrobolograms were analyzed for 1935, 1941, and 1948. The resulting carbon dioxide concentrations for those years were 297.7 ± 5.6 , 298.4 ± 6.3 , and 308.3 ± 4.6 ppm, respectively. These results also yield an annual increase of $0.59 \pm .27$ ppm for the average trend for the period of 1935 through 1948.

The method of analysis used to obtain these results is described in detail. It appears to be much less sensitive to the sources of error that have plagued earlier analyses of the same data. The results also offer obvious guidance on steps that may be taken to improve the analysis of the data.

TR012 Seasonal Climate Scenarios for Europe and North America in a High- CO_2 , Warmer World
(DOE/EV/10098-5, August 1984, 70 pp.)

J. P. Palutikof, T. M. L. Wigley, and J. M. Lough, University of East Anglia, Norwich, United Kingdom

This report presents work done to determine possible patterns of climate change in Europe and North America associated with a global CO_2 -induced warming. The scenarios presented are based on warm and cold periods from the twentieth-century instrumental record. Four sets of scenarios were prepared, each using different criteria for the selection of data used in the construction process. One of these sets is based on twenty-year time-scale data from the period of warming that occurred during the early twentieth century. Since this warming may be partly attributed to increasing CO_2 , and since the warming effect of CO_2 is a medium to long time scale phenomenon, this particular scenario is preferred over the others.

The regional patterns of three surface parameters are discussed for the different scenarios: sea level pressure, temperature, and precipitation. Contrasts that arise between the scenarios because of

differences in the construction method are critically examined. Where the construction process allows, maps are also presented of the change in temperature and rainfall variability.

Although contrasts do occur between the patterns of the four scenarios for Europe, there are also some notable similarities. Winters are expected to become colder (and more variable) over large parts of the continent. This cold zone is associated with an increase in blocking frequency. Rainfall should decrease overall in spring and summer, whereas autumn and winter should be wetter in a warm world. The changes for both temperature and rainfall can be related to the scenario pressure patterns.

The North American scenarios for temperature and pressure exhibit much less inter-seasonal contrast than is the case for Europe. Temperatures are shown to be generally higher throughout the year in a warm world. Of the three scenarios for which temperature maps are presented, only that based on long time scale changes during the early twentieth century warming shows any extensive development of cooler conditions over continental areas. Temperature variability should be lower. North America shares with Europe indications that winters will be wetter, but autumns are expected to be mainly drier.

An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO₂
(DOE/OR/21400-1, September 1984, 109 pp.)

TR013

J. A. Edmonds and J. Reilly, Institute for Energy Analysis

J. R. Trabalka and D. E. Reichle, Oak Ridge National Laboratory

This report discusses the probable rates and potential range of future CO₂ emissions and estimates a range of future atmospheric CO₂ concentrations through the year 2075. Historic fossil fuel usage to the present, increasing at a rate of 4.5% per year until 1973 and at a slower rate of 1.9% after 1973, was combined with three scenarios of projected emissions growth ranging from about 0.2 to 2.8% per year to provide annual CO₂ emissions data for two different carbon cycle models. The emissions scenarios were constructed using an energy-economic model and by varying key parameters within the bounds of currently expected future values. The extreme values for CO₂ emissions in the year 2075 of about 500 to 1500 ppm, with a median of about 700 ppm. The time at which atmospheric CO₂ would potentially double from the preindustrial level ranges from year 2025 to >2075. The practical programmatic value of this forecast exercise is that it forces quantitative definition of the assumptions and the uncertainties, which are the basis for understanding the natural biogeochemical cycle of carbon and both historic and future human influences on the dynamics of the global cycle. Assumptions about the possible range of future atmospheric CO₂ levels provide a basis on which to evaluate the implications of these changes on climate and the biosphere.

The Changing Pattern of Fossil Fuel CO₂ Emissions
(DOE/OR/21400-2, September 1984, 24 pp.)

TR014

R. M. Rotty, G. Marland, and N. Treat, Institute for Energy Analysis

This report analyzes the fossil fuel CO₂ emissions from developing nations of the world compared with emissions from developed nations during the past three decades. The world was divided into

For the next few decades, increases in atmospheric CO₂ concentrations will be largely determined by fuel policies in the developed nations of the world. However, before the middle of the next century, fuel policies of the rapidly growing nations will become extremely important, if not dominant, in the world CO₂ picture.

TR015 A Proposed Reference Set of Scenarios for Radiatively Active Atmospheric Constituents
(DOE/NBB-0066, October 1984, 51 pp.)

D. J. Wuebbles, M. C. MacCracken, and F. M. Luther, Lawrence Livermore National Laboratory

The development of reference scenarios for coordinated scientific investigations of the effects of man-made trace species emissions necessary both for model intercomparisons and governmental decision-making is needed. The species that should be considered include; CO₂, chlorocarbons, stratospheric ozone, tropospheric ozone, methane, nitrogen oxides, nitrous oxide, tropospheric aerosols, carbonaceous and other light-absorbing aerosols, stratospheric aerosols, carbon monoxide, hydrocarbons, and water vapor.

This report proposes a set of scenarios for past and future concentrations of radiatively active atmospheric constituents. The following concentrations may be reached in the next century: CO₂, 340 to 680 ppmv; CH₄, 1.7 to 3.4 ppmv; N₂O, 302 ppbv to 375.5 ppbv; CFC-11, 0 to 744.8 pptv; and CFC-12, 0 to 1789.5 pptv. The report stresses the major uncertainties underlying our understanding of the budgets of the species and the uncertainties in projecting future changes in societal and economic actions. The scenarios are intended to promote discussion leading to generally accepted sets of scenarios that can serve not as a forecast, but as a reference for all research groups using the continental and global-scale chemical interactions and climatic effects of these concentrations.

TR016 A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S.
(DOE/CH/00016-2, December 1984, 76 pp.)

M. Steinberg, H. C. Cheng, and F. Horn, Brookhaven National Laboratory

The U.S. contributes about 30% of the world's total man-made CO₂ emissions; utilities are responsible for about 30% of the U.S. total. This report summarizes research on the removal, recovery, and disposal of CO₂ from U.S. utilities as one option for preventing the "global greenhouse effect."

The removal and recovery system evaluated in this report is based on an absorption/stripping system using an improved stack gas scrubbing solvent. The recovered CO₂ is then liquefied for transmission to the ultimate disposal site. The CO₂ control process is integrated with the power plant operation in that low-pressure steam from the power-generating turbines is used to regenerate the solvent. For 90% removal of CO₂, the efficiency of the power plant is reduced from the conventional 38% to a value of 35%. Three methods of disposal are discussed: (1) injection into the 500-m-deep ocean below the thermocline, about 100 miles off the U.S. coastal waters; (2) storage in depleted oil and gas wells; and (3) storage in excavated salt caverns.

The report recommends evaluating this type of control system in other nations that are major CO₂ contributors. It is estimated that the worldwide application of a CO₂ control system could reduce the annual incremental CO₂ concentration by as much as 32%.

**A Climatic Data Bank for Northern Hemisphere Land Areas,
1851–1980**

TR017

(DOE/EV/10739-2, January 1985, 335 pp.)

R. S. Bradley, University of Massachusetts

P. M. Kelly, P. D. Jones, and C. M. Goodess, University of East Anglia, Norwich, UK

H. F. Diaz, NOAA/ERL

A necessary prerequisite for studies of climatic fluctuations and the causes of climatic variability is a comprehensive set of long-term climatic data for as wide an area as possible. This report documents a new compilation of long-term temperature and precipitation station data for the Northern Hemisphere. The authors surveyed libraries, archives, and data centers to obtain climate data to supplement and improve existing data banks. While the authors report long-term data on mean monthly temperatures and monthly precipitation totals, the primary focus is on the former.

More than 700 temperature and 120 precipitation records extending back into the 19th Century have been incorporated into the data bank. Problems that contribute to potential inconsistencies in the records are discussed (particularly changes in methods of computing mean daily temperature). The temperature data have been used in producing a gridded set of departures from a reference period (1946–1960). The authors discuss problems associated with changes in spatial data coverage with reference to the computation of the "hemispheric" average temperature through time.

[The data set is available on tape (NDP-012) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

A Global Paleoclimatic Data Base for 6000 Year B.P.

TR018

(DOE/EV/10097-6, February 1985, 155 pp.)

T. Webb, III, Brown University

The testing of climate-model simulations for past climates requires subcontinental to global maps of paleoclimatic data. Such maps reveal the magnitude and pattern of climatic variables at enough model grid-points that useful comparisons are possible. This report documents a global data base of pollen, lake-level, and marine plankton data for 6000 year B.P. (the mid-Holocene period); a total of 797 stations are included. This data base provides a core of paleoclimatic information for 6000 year B.P. to which other sources such as ice cores, paleodunes, paleosols, and fluvial geomorphology data can be added.

Pollen data record the broad-scale vegetational patterns that are related to climate. Lake-level data record the relative water depth in lakes and thus provide records of past changes in moisture. Marine plankton data contain information about the geographic distribution of plankton, which (like vegetation) reflect climatic patterns.

Pollen data are available from eastern North America, Alaska, Europe, the Soviet Union, South America, and New Zealand. Lake-level data exist for Australia, Africa, southwestern Asia, western North America, eastern North America, and South America.

Marine plankton data are mainly available from the North Atlantic and northwestern Indian Oceans, but isolated samples exist for the Pacific and Southern Oceans.

Estimated temperature values are presented for eastern North America, Europe, and the ocean samples. Precipitation is estimated for central North America and isolated sites in India and Africa. The data are displayed on maps, and the site locations and other descriptive information are tabulated.

[The data set is available on tape (NDP-011) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

TR019 Carbon Dynamics of Northern Hardwood Forests: Gas Exchange Characteristics

(DOE/EV/10091-1, February 1985, 70 pp.)

T. W. Jurik, G. M. Briggs, and D. M. Gates, University of Michigan

There is considerable interest in the response of plants to increased mole fractions of CO₂ in the atmosphere. The objective of the research reported in this document is to quantify the carbon dynamics of northern hardwood forests and to predict the response of these forests to changing environmental conditions in the future, particularly to increases in CO₂ levels. This report presents studies of physiological responses in relation to environment, based on field studies at five sites at the University of Michigan Biological Station near Pellston, Michigan. Leaf CO₂ exchange and conductance for water vapor were measured in situ using a mobile laboratory. Measurements of leaf conductance for water vapor were also made with a portable porometer. Leaf water potential was measured in the field with a Scholander-type pressure bomb. Photosynthesis; leaf CO₂ exchange rate (CER); leaf conductance; transpiration; water use efficiency (WUE); leaf water potential; gas exchange of leaves, stems, and twigs; and soil respiration were studied.

The optimal temperature for CER was 23 to 25C for leaves growing in the sun and 20 to 24C for those growing in the shade. In saturating CO₂ and saturating light, the temperature optimum for CER shifted upward to 33 to 38C, and maximum CER was more than doubled. Red oak, red maple, and big-tooth aspen have increased WUE in high CO₂.

There is now considerable information on variation in CER and photosynthetic capacity of a single leaf with environmental conditions. Variation among leaves in a given micro-environment and among different microenvironments is known for several physiological characteristics. Variation as a function of habitat (e.g., site fertility) is less understood.

Reconstruction of Past Atmospheric CO₂ Contents from the Chemistry of the Contemporary Ocean: An Evaluation
(DOE/OR-857, March 1985, 79 pp.)

TR020

W. S. Broecker and T. Takahashi, Lamont-Doherty Geological Observatory

T.-H. Peng, Oak Ridge National Laboratory

This report summarizes attempts to reconstruct the CO₂ using contemporary ocean data. Although a beautiful idea, this approach becomes a geochemical nightmare because the uncertainties in the reconstructions will always be larger than the uncertainties ultimately available from other approaches (e.g., ice cores and carbon 13 records). Thus, the value of the ocean data lies in understanding oceanic processes rather than in reconstructing past atmospheric CO₂ contents. When the history of atmospheric CO₂ has been reconstructed from ice core CO₂ and carbon 13 records, then the ocean distribution of CO₂ can be used to constrain some of the current uncertainties in models of the uptake of fossil fuel CO₂ by the ocean.

A Two Dimensional CO₂-Ocean Model Including the Biological Processes
(DOE/NBB-0070, May 1985, 33 pp.)

TR021

C. F. Baes, Jr. and G. G. Killough, Oak Ridge National Laboratory

The purpose of the research reported in this document was to develop a 2-dimensional ocean model that includes biologically controlled processes (photosynthesis and calcium carbonate precipitation) to (1) determine if these processes can be represented with sufficient simplicity to permit rapid computation of the steady-state distribution of carbon in a many-box model, and (2) to conduct various time-integrations from the steady-state initial condition to examine how the response to increasing atmospheric CO₂ depends on the forcing of the model. The authors' approach differs from previous approaches in that (1) they model half a world ocean as a single water volume extending from the equator toward one pole and (2) they describe the flow of water between boxes in the idealized ocean in terms of a small number of parameters with the dimension of diffusivities.

Atmospheric carbon content depends on photosynthesis and the concentration of nutrients, a finding consistent with earlier estimates from one-dimensional models. The effects of circulation rate and warming are secondary. The rate of uptake by the model ocean at any given time in the past is found to vary linearly with the excess carbon in the ocean and in the atmosphere; this suggests that the current rate of carbon uptake by the real oceans may be strongly affected by the forcing that occurred over the previous century or so, and that a model cannot be tested against the current response of the oceans unless the excess carbon taken up in past years can be determined. While the airborne fraction (AF) of excess carbon (airborne + oceanic) in the years just after 1980 depends on previous history, integrating to the year 2100 shows that AF becomes more dependent on total excess carbon and its rate of growth. For the rapid-release scenario, AF reaches values greater than 0.8 by the year 2100.

TR022 A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere

(DOE/EV-10098-2, July 1985, 251 pp.)

P. D. Jones, S. C. B. Raper, B. Santer, B. S. G. Cherry, C. Goodess, P. M. Kelly, and T. M. L. Wigley, University of East Anglia, Norwich, UK

R. S. Bradley, University of Massachusetts

H. F. Diaz, NOAA/ERL

This report consists of a compilation of 2,666 station records of monthly surface-air temperatures for the Northern Hemisphere. To use these data to form a gridded data set for the Northern Hemisphere the homogeneity of each of these records, where provided, was assessed. The results of this assessment are presented in the report and stations are classed as immediately usable, corrected, or uncorrectable. Full details of how this was achieved for each station are presented in tabular form. Of the 2,666 station records, 1,584 were used to produce the gridded temperature data set. Temperature anomalies were calculated for monthly means for the reference period 1951-70 using the homogenized data. Anomalies at each point of a 5° latitude by 10° longitude grid were interpolated from the station data for each month for the period 1851 to 1984.

[The data set is available on tape (NDP-020) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

TR023 The Effect of Elevated Atmospheric CO₂ on Plant Communities

(DOE/EV/04329-5, July 1985, 39 pp.)

F. A. Bazzaz, K. Garbutt, and W. E. Williams, Harvard University

This report summarizes exploratory research on the effects of elevated carbon dioxide concentrations on the growth of a variety of ecologically important plants. Although the plant responses were subtle and complex, the following broad conclusions could be drawn from the study:

1. Different species showed different degrees of growth enhancement, suggesting that competition relationships may have changed.
2. Flowering and fruiting did not always change to the same degree, or even in the same direction, as total plant weight. Thus, experiments not carried through to fruit maturity can lead to incorrect conclusions.
3. Because of fruiting and flowering changes, some effects from exposure to increased carbon dioxide concentrations were not completed for several generations. Thus, evolutionary changes in the characteristics of the individual species may be expected.
4. Elevated carbon dioxide can have a slight protective effect against other pollutants.

Methods of Uncertainty Analysis for a Global Carbon Dioxide Model
(DOE/OR/21400-4, July 1985, 41 pp.)

TR024

R. H. Gardner and J. R. Trabalka, Oak Ridge National Laboratory

This report describes the results of applying Monte Carlo methods of uncertainty analysis to Oak Ridge National Laboratory's World Carbon Cycle Model to examine the time-dependent variability of predicted values of atmospheric carbon dioxide and relate them to uncertainties associated with model parameters. The report presents the details of the statistical methods used to reveal significant relationships between model parameters and predictions. When emission rates of carbon from fossil fuel combustion were considered a part of the CO₂ release scenario (e.g., fixed for all model simulations) then, (1) predicted atmospheric concentrations of carbon dioxide showed relatively low levels of variability through time, (2) parameter importance levels were time dependent, and (3) model parameters associated with absorption of carbon in the ocean and release rates of carbon from forest clearing accounted for over 90% of the uncertainty of predicted atmospheric CO₂ in the year 2075. The implementation and refinement of these techniques for the carbon cycle model now make it possible to examine, in a manner consistent with available data, the uncertainties associated with other scenarios of carbon emission rates and to compare the results in a quantitative manner with those of other models.

The Stability of Low-Latitude Sea Surface Temperatures: An Evaluation of the CLIMAP Reconstruction With Emphasis on the Positive SST Anomalies
(DOE/ER/60167-1, October 1985, 57 pp.)

TR025

W. L. Prell, Brown University

This report examines the stability of low-altitude sea surface temperatures over the past 18,000 years and evaluates the evidence for positive sea surface temperature anomalies (i.e., warmer than present) in the CLIMAP 1981 reconstruction of the oceans during the last glacial maximum about 18,000 years ago. A global array of planktonic foraminiferal population data were compiled and then applied both to CLIMAP temperature equations and to the modern analog technique of temperature estimation. The modern analog technique of estimating temperature is substantially different from the CLIMAP method and gives equal or high correlation with observed data and lower standard estimates of error than comparable CLIMAP equations. The comparison indicates that the estimates of relatively stable low-latitude temperatures and, in some cases, warmer sea surface temperatures are inherent in the planktonic foraminiferal populations and are not a function of CLIMAP's 1981 method of temperature estimation.

Carbonate Chemistry of the Bering Sea
(DOE/EV/10611-5, September 1985, 79 pp.)

TR026

C.-T. A. Chen, C.-L. Wei, and M. R. Rodman, Oregon State University

The dynamics of atmospheric-ocean exchanges of carbon dioxide, and of carbon dioxide fluxes with the oceans, are important, but largely unquantified factors in understanding the global carbon cycle. This report has the following goals with respect to defining the carbonate chemistry of the Bering Sea: (1) to obtain the first winter oxygen and carbonate data in the Bering Sea; (2) to

evaluate seasonal, cross-frontal, and cross-ice-edge variations of oxygen and carbonate chemistry; (3) to estimate the effect of pack ice on air-sea exchange of gases; (4) to estimate the penetration depth of the excess, anthropogenic CO₂ in the Bering Sea; and (5) to compare the results with data reported in the literature and to estimate the importance of the Bering Sea in removing the excess CO₂ from the atmosphere.

The analyses in this report are based on data collected aboard the U.S. Coast Guard icebreaker *Polar Sea* in the late winter of 1983 (part of the outer Continental Shelf Environmental Assessment Program) and on summer data available in the literature. Wintertime oxygen, pH, alkalinity, and calcium data across the marginal ice zone of the central and southeastern Bering Sea shelf are analyzed and compared with summer data.

The Bering Sea pack ice impedes but does not stop the air-sea exchange of gases. Mixing dominates the distribution of chemical properties on the shelf. Excess CO₂ has probably saturated the Bering Sea shelf water but does not penetrate more than 1000 m in the Aleutian Basin. No excess CO₂ was detected in the bottom waters. Overall, the Bering Sea contains $0.19 \pm 0.05 \times 10E^{15}$ g excess carbon.

TR027 A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere
(DOE/EV/10098-6, February 1986, 73 pp.)

P. D. Jones, S. C. B. Raper, C. M. Goodess, B. S. G. Cherry, and T. M. L. Wigley,
University of East Anglia

A truly representative time series of average temperatures for Earth can only be achieved by incorporation of data from both the land and marine areas of both hemispheres (most studies to date have been representative of conditions over only the Northern Hemisphere land masses). In this study, a compilation of 610 station records of monthly surface air temperature has been assembled for the Southern Hemisphere, north of 62.5°S. The basic source of data was the digitized form of the World Weather Records; additional data were incorporated for Indonesia, Australia, some Pacific islands (particularly Tahiti), New Zealand, Peru, and Antarctica.

To use these data to reconstruct the first grid-point temperature data set for the Southern Hemisphere, the homogeneity of each of the station records has been assessed. Each station has been classed into one of three groups: immediately usable, corrected, or uncorrectable. The results are presented in tabular form.

Of the 610 station records, 293 were used to produce a gridded data set on a 5° latitude by 10° longitude grid between 5° S and 60° S, inclusive. Grid-point anomalies for 1851–1984, with respect to the reference period 1951–1970, were interpolated from station data using a simple inverse-distance weighting algorithm. To produce a best-possible data set, Antarctic data were included after they became available in 1957.

The time series of the Southern Hemisphere area average shows little overall trend during the nineteenth century. After 1900, the series shows a warming trend to the mid 1940s. Between about 1945 and 1970, no trend can be seen. Since 1970 a strong warming trend has set in. The three warmest years of the entire record are 1980, 1981, and 1983. The overall warming trend since 1900 is about 0.5°C, of which roughly 0.3°C occurred between 1900 and 1945 and 0.2°C since 1970. The history of the land-based Southern Hemisphere temperature series is, therefore, not dissimilar to that for the Northern Hemisphere. However, the early twentieth-century warming up to 1940 is smaller in

magnitude, and the cooling evident in the Northern Hemisphere between 1940 and 1965 appears only as a hiatus in the longer-term warming trend.

[The data set is available on tape (NDP-020) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO₂ on Marine Fisheries from the Northeast Pacific Ocean TR028
(DOE/NBB/0075, December 1985, 139 pp.)

R. M. Strickland, D. J. Grosse, A. I. Stubin, G. K. Ostrander, and T. H. Sibley, University of Washington

Increased concentrations of atmospheric CO₂ will have direct effects on climate and on dissolved CO₂ in the oceans and indirect effects on abiotic (physical and chemical) properties of the oceans. Effects of increased concentrations of dissolved CO₂ are expected to be minimal, except for the possible effects of increased availability of trace metals. The abiotic effects that are most important for marine fisheries are changes in temperature, ice cover, turbulence, and current patterns in the upper layer of the ocean.

Equally important fishery impacts may be transmitted via biotic effects on prey and predators of immature fish. The most promising avenue for both general and specific climate-related fishery research at this time is the effects of the abiotic environment on the planktonic food supplies of larval and juvenile fish, especially as mediated by primary production. Global warming will shift the present latitudinal domains of most fish species poleward, but the magnitudes of this shift and of possible associated changes in fishery yield are unknown. Uncertainty is related to lack of knowledge of the ways that temperature and other factors regulate fish populations, as well as to uncertainties in the rate and magnitude of changes in the environment. Uncertainty also arises because of differing species characteristics and local factors such as rivers, bathymetry, and ice that makes it difficult to generalize among fisheries. Four northeast Pacific region case-study species were studied to determine individual fishery responses to climate change (Alaska pollock, *Theragra chalcogramma*; Pacific herring, *Clupea harengus pallasi*; pink shrimp, *Pandalus borealis*; and yellowfin sole, *Limanda aspera*). Because unique properties of individual fisheries are as important as the general properties of all fisheries for determining climatic effects, the ability to project the effects of climate change on fisheries without performing detailed case studies is limited. Likewise, it is difficult to extrapolate from the results of the present case studies to other fisheries. These results are particularly inapplicable to other major categories of fisheries, including open-ocean, upwelling, and tropical and subtropical shelf fisheries. Such fisheries should be the focus of additional case studies. Possible temperature effects on the incidence of disease and parasitism in fish also should be investigated.

Ultimately, greater understanding of the effects of climate on fisheries will depend on improvements in coordinated large-scale data gathering in the field. In the interim, useful supporting studies can be performed on the small-scale laboratory responses of fish larvae and plankton to abiotic changes (especially CO₂, temperature, and turbulence) and on developing quantitative relationships using these results and other existing field and laboratory data. In particular, there is sufficient theoretical and empirical knowledge to justify beginning the development of a global marine primary-production model, which would have the corollary benefit of complementing global carbon cycle models.

**TR029 Preliminary Data Report for the INDIVAT Number 1 and INDIGO 1/
INDIVAT 3 Cruises in the Indian Ocean**
(DOE/NBB/0074, January 1986, 106 pp.)

C.-T. A. Chen, College of Oceanography, Oregon State University

A. Poisson and C. Goyet, Universite Pierre et Marie Curie, Paris

The main objective of this research was to quantify the oceanic penetration of excess CO₂ by using carbonate data directly. The specific objectives were (1) to obtain the first winter carbonate data in the South Indian Ocean, which is near the major point of origin for the bottom waters in the world oceans; (2) to evaluate seasonal and cross-frontal (Subtropical and Antarctic Front) variations of carbonate chemistry; (3) to estimate the depth of penetration of the excess man-derived CO₂ in the Indian Ocean from both carbonate and transient tracer data; and (4) to compare the results with reported literature data.

This report summarizes the experimental data and a limited preliminary analysis from the first two of a series of cruises scheduled for the Indian Ocean for the period 1984 to 1987. When the tracer data become available, a full report will be published.

Preliminary results of this study are:

1. The surface pH and normalized nitrate, alkalinity, and total CO₂ values correlated linearly with temperature.
2. Small deviations from the linearity are related to the Subtropical Front and the equatorial upwelling.
3. Large nitrate variations occurred in surface waters collected at the same station but in different seasons; however, there was less variation between normalized nitrate concentrations in waters with the same temperature.
4. There appeared to be a seasonal difference in alkalinity and total CO₂.
5. The decrease in alkalinity and total CO₂ between the Antarctic Waters and the Indian Central Waters from north of the Subtropical Front may be caused by the decrease in nitrate and the increase in temperature.
6. The remnant North Atlantic Deep Water, which has a weak salinity signal, can be identified by pH and total CO₂ data, but nutrient, oxygen, and calcium data also help in tracing this water.
7. The alkalinity and total CO₂ data for subsurface waters agree well with GEOSECS data for GS 427 and 428 but not for GS 429.

These results permit for the first time an evaluation of the variations in the carbon and nitrogen cycles in the Antarctic Intermediate Water in the Indian Ocean with reference to the source water in winter.

Effects of Energy Technology on Global CO₂ Emissions
(DOE/NBB/0076, April 1986, 92 pp.)

TR030

H. C. Cheng, M. Steinberg, and M. Beller, Brookhaven National Laboratory

This study was done to investigate the effects on global energy consumption and CO₂ emissions of end-use and electricity-generation technologies, with emphasis on efficiency improvement. The following are the conclusions of the study.

1. The large margins of efficiencies between present and future improved energy technologies, and the wide variations in efficiency levels among countries, indicate considerable room for major long-term reductions in energy consumption through technological improvements.
2. Savings achievable by more efficient end-use and electricity-generation technologies, if effectively implemented, are estimated as about 145 exajoules (10¹⁸ joules) of liquids fuels, 118 exajoules of gas fuels, and 236 exajoules of solid fuels, with an overall fossil-fuel savings of 500 exajoules, which is about 58% of the fossil-fuel demand without technology improvements for year 2050.
3. The distribution of these fossil-fuel savings by end-users is 175 exajoules (39%) for residential and commercial users, 227 exajoules (46%) for industrial users, and 76 exajoules (15%) for transportation users. Breakdown by fuel type for each type of user shows that technologies could produce savings in solid fuels for industrial users and in liquid fuels for transportation users.
4. The regional breakdown of the overall fossil-fuel savings of 500 exajoules, is 97 exajoules (19.5%) from the U.S., 101 exajoules (20%) from Canada and Western Europe, 56 exajoules (11%) from OECD Pacific, and the remaining 245 exajoules (49%) from the Soviet Union, China, and all the other developing countries. Except for the USA, the general global structure of fuel savings is 50% from solid fuels, 26% from liquids, and 24% from gases. Because the USA has a larger demand for liquid fuels, especially by transportation users, than all the other regions, it has a higher potential for liquid fuel savings through technology improvement.
5. The associated overall reduction of carbon emission in year 2050 is 10 petagrams (10¹⁵ g), i.e., carbon emissions could be reduced from 17 petagrams without efficiency improvements to 7 petagrams with the efficiency improvements discussed in this study—a 59% reduction. The largest share of the reduction is from solids, 5.6 petagrams carbon, with liquids contributing 2.8 and gases 1.6 Pg C.
6. The distribution of the overall reduction of CO₂ emissions by end-users is 3.8 Pg C (38%) for residential and commercial users, 4.7 (47%) for industrial users, and 1.5 (15%) for transportation users.
7. The regional breakdown of the overall reduction of 10 petagrams of carbon emissions is 1.9 Pg C (19%) from the U.S., 2.0 (20%) from Canada and Western Europe, 1.1 (11%) from the OECD Pacific, and the remaining 5.0 Pg C (50%) from the Soviet Union, China, and all the other developing countries. Hence, the developing regions have the same potential for reducing CO₂ emissions as do the developing regions in year 2050 through technology efficiency improvements.

8. The largest share of energy savings by residential and commercial users is from space conditioning technologies, about 75% of the fossil-fuel savings and 35% of the electricity savings, with water-heating technologies accounting for most of the remaining fossil-fuel savings (20%) and about 15% of the electricity savings. For industrial users, about 80% of the fossil-fuel savings are from improvements of efficiencies in process heat, and about 80% of the savings in electricity are from improvements in electric drives. Automobiles and trucks account for about 80% of the liquid-fuel savings by transportation users. Overall CO₂ emission in year 2050 could be reduced by 46% compared with that without technology improvement, through improvements of these technologies; this is about 80% of the reduction due to general technology improvements.
9. Use of the savings in electricity generated from non-fossil energy (i.e., nuclear, solar, and hydro) due to technology improvement to replace demand for electricity generated from fossil fuels produces additional savings of 13 exajoules of liquids, 14 exajoules of gases, and 56 exajoules of solids. Combining the improvements in end-use and electricity-generation technologies with such replacement raises the total fossil-fuel savings in year 2050 to 580 exajoules, which is 68% of the fuel demand without the technology improvements. The associated reduction of CO₂ emission is 11.8 petagrams of carbon. This means that CO₂ emissions in year 2050 could be reduced by 68%, compared with 59% without such replacement.
10. The actual savings of fossil fuels should be larger than the estimates given if account is taken of the energy needed for producing and transporting the saved energy, and the actual reduction of CO₂ emission should be correspondingly larger.
11. The total capital costs for technology implementation for year 2050 are about 6.0 and 24.0 trillion 1980 USA dollars, resulting in total returns on investment based purely on fuel savings of about 8% and 10% for the USA and the world, respectively. The industrial sector has more potential than the other users for reducing CO₂ emissions (50% of the overall reduction) with low capital requirements for technology implementation (6% of overall capital requirements) and high return on investment (40%).

TR031 The Impact of Climate Change from Increased Atmospheric Carbon Dioxide on American Agriculture
(DOE/NBB/0077, May 1986, 100 pp.)

W. L. Decker, V. K. Jones, and R. Achutuni, University of Missouri

This report summarizes the current knowledge of potential effects of CO₂-induced climate change on agriculture in the United States. Emphasis is placed on the fourteen-state midwestern region (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Texas, and Wisconsin) and on four crops (corn, soybeans, wheat, and sorghum) and animal production. The report begins with a review of American agriculture by describing developments in the twentieth century, natural and institutional resources that support the farm enterprise, and the magnitude of production of crops and livestock. The report then discusses the effects of climate change on crop production (with a summary of the direct effects of CO₂ on plants); topics include changes in growing-degree days, cropping patterns, genetic selection, farm management alternatives, and pest management. Next the report covers the effects of climate change on animal production in relation to the following topics: effects of temperature, rainfall, humidity, and day length; animal management; genetics; and effects of climate on forages such as grasses and legumes. In the summary chapter, knowns, unknowns, and required research are presented for each of eight issues or concerns (for example, water availability, genetic development).

A Comparison of Tropical Forest Surveys
(DOE/NBB/0078, June 1986, 66 pp.)

TR032

J. Molofsky, Butler University

C. A. S. Hall, Cornell University

N. Myers, Consultant, Oxford, England

Over the years several assessments of tropical forest areas have been made. This report examines the two most recent studies of tropical forest areas and rates of forest loss: Norman Myers' Conversion of Tropical Moist Forests (1980), and the FAO/UNEP Tropical Forest Resources Assessment Project (1981a,b,c) to identify and clarify discrepancies between them. These reports were chosen for comparison because the apparent discrepancy between their respective estimates of deforestation rates has been the basis of a continuing controversy. Myers' report, prepared under the auspices of the National Academy of Sciences, was concerned principally with the conversion of virgin forests to other land use and the resulting extinction of tropical species. His report concluded that tropical moist forests are being converted from a primary state to various human-impacted categories at a rate of 200,000 km² per year, but only about one-half of this amount is permanently deforested. The remainder is cleared, cultivated for a few years, and allowed to recover in a process called shifting cultivation. Although shifting cultivation allows a forest to recover, the regrowth may exhibit reduced biological diversity and biomass. The FAO/UNEP (1981a,b,c) report emphasized the availability of forest resources to meet the future fuelwood, housing, and economic needs of UN member states. The report concluded that conversion of forest to nonforest land is occurring at a rate of 73,000 km² per year.

Different definitions apparently have caused a misinterpretation of the results of the two reports. The present paper attempts to identify more precisely the differences between the two studies to integrate the large tropical forest data base from these two sources into a cohesive whole. Specifically, those countries covered in both surveys where the largest differences occur are identified. Then, further research can be directed where it will be most useful. The present study does not assess all discrepancies between the reports of Myers and FAO but only those for countries where both investigators have given specific numbers.

High Accuracy Standards and Reference Methodology for Carbon Dioxide in Air
(DOE/PR-06010-31, June 1986, 101 pp.)

TR033

W. L. Zielinski, Jr., E. E. Hughes, I. L. Barnes, J. W. Elkins, and H. L. Rook, National Bureau of Standards

This report summarizes the activities and accomplishments of a three-year NBS program for the development of standards and reference methodology for carbon dioxide in air that was designed to:

- Develop defined Standard Reference Materials (SRMs) for CO₂ in air at atmospheric concentrations having a total uncertainty (95% confidence level) not exceeding 0.1 percent relative;

- Assess the equivalency of absolute gravimetry employed by the National Bureau of Standards (NBS) and absolute manometry employed by the Scripps Institution of Oceanography (SIO) for the development of accurate standards for CO₂ in air at atmospheric concentrations; and
- Develop a state-of-the-art isotope dilution mass spectrometer (ID-MS) system and associated methodology to serve as an NBS-based reference method for absolute independent confirmation of CO₂ concentrations in CO₂ in air standards.

The first of these objectives has been realized in the issuance of seven CO₂ in air SRMs in the 300-400 parts-per-million (ppm) range of interest. Each SRM cylinder in these seven SRMs contains a CO₂ in air concentration that is individually certified to be stable for a period of at least two years within a total uncertainty of 0.2 ppm with 95% confidence. The first three of these were issued in 1983, covering nominal concentrations of 330, 340, and 350 ppm. Four additional SRM's were issued in 1985, covering nominal concentrations of 340 and 380 ppm. Two of these four SRMs were certified in size 150 cubic foot cylinders to address the higher volume needs of investigators, while the remaining two were certified in standard SRM size cylinders (30 cubic foot). All four of the latest SRMs also were certified for nitrous oxide levels in the part-per-billion (ppb) range and have information (non-certified) values for methane (1.7-1.8), and for halocarbons F-11 and F-12 in the part-per-trillion (ppt) range. Five additional CO₂ in air SRMs are planned for certification in 1986 at nominal concentrations of 200, 300 (two SRMs), 360, and 1000 ppm.

The second of these objectives was to assess the equivalency between absolute gravimetry (NBS) and absolute manometry (SIO), in order to ensure a scientific basis for the transfer of responsibility for CO₂ in air standards from SIO to NBS. The differences that were observed between CO₂ concentrations assigned by gravimetry by NBS and those measured by SIO using the constant volume manometer (CVM) for multiple intercomparisons were within the limits of experimental error of the two systems. Hence, standards from one system (NBS) can be used interchangeably with standards from the other system (SIO). This achieves one of the primary goals of the program: namely, that NBS standards may be used for calibrating measurements of atmospheric CO₂ without compromising the existing data record, and, further, that the institutionalization at NBS of the availability of standards will ensure the long-term continuity and integrity of this data record for the indefinite future. These intercomparisons represent the completion of a convergence plan prepared at the outset of this program by principal scientists of SIO (C. D. Keeling) and NBS (E. E. Hughes).

The third objective has involved the design, construction, testing, and evaluation of a computer-controlled ID-MS system to serve as an independent reference method for the analysis of CO₂ in air SRMs. In practice, this method would be used to independently verify the accuracy of randomly-selected, gravimetrically-certified CO₂ in air calibrations covering a range of CO₂ concentrations within 300-400 ppm and extensions above and below this range. A separate report detailing the characteristics of this system and its performance will be issued. NBS plans to use this system and its associated methodology as a confirmatory reference method for CO₂ in air SRMs.

Current research extensions to this program include the development of an NBS master calibration curve incorporating numerous primary gravimetric standards covering the 300-400 ppm range and an assessment of the absolute minimum error associated with the preparation of such standards and the development of SRMs. Specifically, this continuing research is directed at (1) the development of a global calibration curve interrelating all NBS primary gravimetric standards within a predictable uncertainty, and (2) a detailed evaluation of the feasibility of further reducing the total uncertainty at 95% confidence for certified SRM concentrations, below its current level of 0.2 ppm (0.6% relative). A separate report describing the results of this extended research will be issued.

Carbonate Chemistry of the North Pacific Ocean
(DOE/NBB-0079, October 1986, 176 pp.)

TR034

C.-T. A. Chen, M. R. Rodman, C.-L. Wei, and E. J. Olson, Oregon State University

R. A. Feely and J. F. Gendron, Pacific Marine Environmental Laboratory, NOAA

The objective of this research was to quantify the oceanic penetration of excess CO₂ by using carbonate data directly, and to understand better the oceanic carbon cycle. Data collected along two longitudinal cruises serve as the main data sources, and supplementary data sets in the literature are selected for delineating the distribution of physical and chemical properties in a wide area of the North Pacific Ocean.

Oxygen, pH, alkalinity, total CO₂, and nutrients are interrelated parameters. Along two longitudinal sections these parameters show a core structure underlying the salinity minimum layer. From these oxidation-related parameters, the researchers concluded that the subsurface water of the eastern North Pacific Ocean is older than that of the western North Pacific Ocean.

Alkalinity data can be used as a water mass tracer. Different water masses reveal their own mixing trends which can be identified when examining the correlation of normalized alkalinity with temperature. The vertical distribution of the normalized alkalinity shows a maximum core at a depth of about 2500 m in the North Pacific Ocean. Calcium carbonate dissolution and circulation in the deep and bottom layers contribute to the formation of the normalized CaCO₃ dissolution rate of 0.060 and 0.053 umol/kg/yr, respectively, referenced to the Weddell Sea Deep Water for waters deeper than 2000 m.

This analysis of carbonate data shows that about 25% of the increase in total inorganic CO₂ in deep water, in its journey from the surface of the Southern Ocean to the depth of the North Pacific, results from inorganic CaCO₃ dissolution. No significant difference in the inorganic carbon/organic carbon ratio exists between the two longitudinal sections. However, the eastern section has a higher total TCO₂ input than that of the western section.

The degree of saturation of calcite and aragonite was calculated from all available data sets. Four selected cross-sections, three longitudinal and one latitudinal, and two three-dimensional graphs show that a large volume of the North Pacific is undersaturated with CaCO₃. The saturation horizon generally shows a shoaling from west to east and from south to north in the North Pacific Ocean. It was found that the lysocline falls at a depth much deeper (about 2500 m deeper) than the saturation horizon of calcite and several hundred meters shallower than the calcium carbonate compensation depth. Results appear to support the kinetic point of view on the CaCO₃ dissolution mechanisms.

Calculations on the excess CO₂ show that its penetration depth is strongly related to circulation. The shallowest penetration depth is less than 300 m found in the eastern equatorial region where upwelling prevails and the deepest penetration depth is deeper than 2000 m off Japan where an interaction of Oyashio and Kuroshio currents is found. These results agree with conclusions drawn based on Freons, tritium, and carbon-14 data. Overall the North Pacific contains $14.7 \pm 4 \times 10^{15}$ g excess carbon.

[The data set is available on tape (NDP-029) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

TR035 An Annotated Inventory of Climatic Indices and Data Sets
(DOE/NBB-0080, November 1986, 195 pp.)

H. A. Hattemer-Frey, Oak Ridge National Laboratory

T. R. Karl and F. T. Quinlan, National Climatic Data Center

This publication describes 34 prominent climatic indices and provides an annotated listing and bibliography of additional indices to help meet the information needs of researchers who are evaluating the effects of increased atmospheric CO₂ levels. The goal was to discuss a wide range of indices that would be useful to scientists working directly in diverse areas of CO₂-climate research and those individuals interested in climate research results for other applied studies.

This publication is a source to consider first to determine what information is available and how knowledge of climatic indices may help investigators meet their research goals.

To ensure that a broad spectrum of indices was considered, indices from the following ten subject areas are included:

(1) Global/Hemispheres, (2) Marine Data Sets, (3) Long-Term Regional and Local Temperature and Precipitation Data Sets, (4) Atmospheric Constituents Data Sets, (5) Upper Air Data Sets, (6) Southern Oscillation/El Niño Data Sets, (7) Solar Data Sets, (8) Proxy Data Sets, (9) Lake Levels and River Flows Data Sets, and (10) Snowcover and Sea Ice Extent Data Sets.

Each description provides a brief but detailed summary of the index's relevance, importance, and derivation. Seventeen descriptor fields were used to describe each index, including primary references, relevant background information, calculation of the index, temporal resolution, spatial coverage, unit of measurement, period of record, reliability, relationship to other indices, application, and citation information.

TR036 Uncertainty in Future Global Energy Use and Fossil Fuel CO₂-Emissions 1975 to 2075
(DOE/NBB/0081, December 1986, 95 pp.)

J. A. Edmonds and J. M. Reilly, Pacific Northwest Laboratory

R. H. Gardner, Oak Ridge National Laboratory

A. Brenkert, Science Applications International Corporation

This report summarizes the results of work with the IEA/ORAU Long-Term Global Energy-CO₂ model to analyze model predictions of future global carbon emissions from fossil fuel use and the uncertainty surrounding such forecasts.

The methods used were the latest techniques of uncertainty analysis along with review and revision of the IEA/ORAU model structure, and review and description of uncertainty surrounding model assumptions and parameters to explore uncertainty in fossil fuel CO₂ emissions over the period 1975–2075. Possible interrelationships among assumptions and parameters, and their effects on overall forecast uncertainty are explored.

The major findings include:

1. The median rate of CO₂ emissions grow at an average annual rate of 1.0 percent per year. This rate is substantially lower than the post World War II experience and lower than that found by earlier studies.
2. Overall uncertainty in the emission rate was found to be considerable. A range of 3.0 percent per year growth in emissions and a decline of 1.4 percent per year are needed to bracket 90 percent of the 400 randomly generated scenarios.
3. Low and declining CO₂ emissions rates appear more likely than past research has indicated. Roughly one quarter of the scenarios show global emissions falling from current levels.
4. The three most important determinants of variation in CO₂ emissions were labor productivity, rate of improvement in end-use energy efficiency, and the income elasticity of demand for energy in the developing world.
5. Based on the analysis of potential correlation among assumptions, model structure plays a key role in the determination of median estimates of fossil fuel CO₂ for energy emissions.
6. Conspicuously absent from the list of key variables were the rate of interfuel substitution and the fossil fuel resource base by fuel type.

**Monthly Mean Pressure Reconstructions for Europe (Back to 1780)
and North America (to 1858)**
(DOE/ER/60397-H1, February 1987, 99 pp.)

TR037

**P. D. Jones, T. M. L. Wigley, and K. R. Briffa, Climatic Research Unit,
University of East Anglia**

Monthly grid-point pressure data are reconstructed from station records of air temperature, precipitation and pressure for Europe, back to 1780, and North America, back to 1858. The reconstructions are based on a principal components regression technique which relates surface pressure patterns to those of the temperature, precipitation and station pressure data. The relationships are derived over a calibration period and the results are tested with independent data from another period. To illustrate the results, examples are given of pressure anomalies over Europe during 1816 (the "year without a summer"), anomalies over both Europe and North America for January and November 1862 (months with particularly strong anomalies), and anomalies over North America during 1884 (the year after Krakatau).

The reconstructions are compared with other monthly mean pressure maps produced by Lamb and Johnson (1966) for Europe for 1780 to 1872 and for North America for 1858 to 1898, and by Kington (1980) for Europe for 1781 to 1785. Both of these map series show systematic biases relative to the present reconstructions. The reconstructed data are available on a magnetic tape.

[The data set is available on tape (NDP-025) from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory.]

TR038 A Data Bank of Antarctic Surface Temperature and Pressure Data
(DOE/ER/60397-H2, June 1987, 52 pp.)

P. D. Jones, University of East Anglia

D. W. S. Limbert, British Antarctic Survey

A data bank of monthly-mean surface air temperature and sea-level or station-level pressures is presented for 29 stations over the Antarctic region south of 60° S. Considerable attempts have been made to locate missing data in nationally published sources and in World Weather Records. By cross-checking neighboring station data, suspect values have been either verified or corrected.

At four sites in the Antarctic Peninsula region, composite records were produced by amalgamating records from a number of short and longer length records at or near the key sites. The four sites were Bellingshausen, Faraday, Esperanza, and Rothera.

The mean Antarctic temperature series produced by Raper et al. (1984) is updated using the same method of calculation.

TR039 The Prospect of Solving the CO₂ Problem Through Global Reforestation
(DOE/NBB-0082, February 1988, 66 pp.)

G. Marland, Oak Ridge Associated Universities and
Oak Ridge National Laboratory

We are confronted with the possibility that it may become necessary to try to limit the increase in atmospheric CO₂ in order to avert adverse changes in the global climate. One short-term approach would be to stimulate the growth of forests to take up in woody matter enough carbon to balance the discharge of CO₂ from fossil fuel burning. This study evaluated the extent to which the area and/or net growth rate (mean annual increment) of global forests would need to be enhanced in order to remove an additional 5×10^9 tons of carbon per year from the atmosphere.

Although it is physically possible to plant large areas of new plantation and/or to stimulate tree growth via advanced silviculture techniques, conflicts in land use and resource allocation are quickly encountered in efforts of sufficient magnitude. The scale of the effort required is approximately equal to doubling the new annual yield of all of the world's closed forests or planting new fast growing forests over an area equivalent to the total of global forest clearing to date. The cost of such a scheme is immense but it needs to be compared with the costs of other approaches to dealing with atmospheric CO₂ or of coping with the attendant changes in climate. It is clear that although it is impractical to think in terms of solving the CO₂ problem through forestry alone, forestry could play a significant role.

A Primer on Greenhouse Gases
(DOE/NBB-0083, March 1988, 100 pp.)

TR040

D. J. Wuebbles, Lawrence Livermore National Laboratory

J. Edmonds, Pacific Northwest Laboratory

The purpose of this document is to provide a reference summarizing current understanding of basic information for important greenhouse gases. Each of the gases included is recognized to be important to the future state of global atmospheric chemistry and climate. Included as greenhouse gases are those of direct radiative importance to climate, those that act as radiative precursors, and those of importance as intermediate constituents because of their chemical activities. Knowns, unknowns, and uncertainties for each gas are described. This document focuses on information relevant to understanding the role of energy and atmospheric chemical and radiative processes in the determination of atmospheric concentrations of greenhouse gases.

The document takes the form of a large table. Two summary tables highlight the contents. One outlines the basic information given in the main document table, and the other gives an indication of the relative potential importance of the gases to chemistry and climatic effects on the global atmosphere.

In the course of the development of this document several conclusions became clear. The most important of these conclusions are:

1. There are major uncertainties regarding the source budgets for key gases including CH₄, CO, N₂O, and NO_x. These uncertainties greatly exceed those for the sources of CO₂ emissions.
2. Of particular concern is the relatively primitive evaluation of the relationship between energy activities and emissions of these gases, despite the fact that these gases are estimated to have energy sources amounting to between 32 and 75% of all man-made sources.
3. The relationship between energy and emissions sources for the gases evaluated in this study is stronger than had been anticipated before the study began.
4. Chemical processes in the atmosphere represent an important link between energy and other emissions sources and the composition of the atmosphere. Understanding atmospheric composition is essential to detecting and quantifying the role of energy and CO₂ in climate change.
5. More definitive studies of the interactions between chemical and climatic processes are necessary to facilitate an early detection of a CO₂/climate-change signal. This is intended to be a living document to be updated as additional information in important greenhouse gases becomes available. The reader is invited to contribute to the updating process. This version of the report did not consider several currently minor but potentially important greenhouse gases. Namely, non-methane hydrocarbons and additional chlorocarbons, particularly CFC-113, CCl₄, and CH₃CCl₃, deserve consideration.

TR041 Regional Intercomparisons of General Circulation Model Predictions and Historical Climate Data

(DOE/NBB-0084, April 1988, 291 pp.)

Stanley L. Grotch, Lawrence Livermore National Laboratory

This study is a detailed intercomparison of the results produced by four different General Circulation Models (GCMs) that have been used to project the climatic consequences of a doubling of the atmospheric CO₂ concentration. The results for the models developed by groups at the National Center for Atmospheric Research (NCAR/CCM, Washington and Meehl, 1984), the Geophysical Fluid Dynamics Laboratory of NOAA (GFDL, Manabe and Wetherald, 1987), and the Goddard Institute for Space Studies of NASA (GISS, Hansen, et al., 1984) have been described by Schlesinger and Mitchell (1985) in the DOE state-of-the-art (SOA) report, "Projecting the Climatic Effects of Increasing Carbon Dioxide." The fourth model examined here is the Oregon State University GCM (OSU, Schlesinger, 1986), results for which did not become available until after publication of the SOA.

We have chosen to examine only two model variables here: (1) surface air temperature, and (2) precipitation. We consider these variables for both seasonally and annually averaged periods, for both the current climatic conditions and the predicted equilibrium changes after a doubling of the CO₂ concentration. For the current climate (1 × CO₂), the model results for these two variables were compared with each other and with several data sets representing observed climate conditions over recent 15 to 30 year periods; the domain covered is global, although the adequacy of data over many regions is very limited. The grid resolution of the different models varies from 4° latitude by 5° longitude to 8° latitude by 10° longitude; the data are typically available with similar resolution. Thus, each data point (on the model or observation grid) represents a region of about 400 km by 400 km or larger, or roughly the size of Colorado, even though regions of this size may have very diverse local climates.

In Schlesinger and Mitchell (1985), the analyses emphasized the global scale nature of the models. Here, the major focus is the intercomparison of models and data over a range of scales: global, hemispheric, zonal, continental, and regional (typically representing 5 to 20 model gridpoints). The fundamental question addressed is: "How well do the predictions from different GCMs agree with each other and with historical climatology over different areal extents, from the global scale down to the range of only several gridpoints?"

The major conclusion of this study is that, although the models often agree well when comparing seasonal or annual averages over large areas, substantial disagreements become apparent as the spatial extent is reduced, particularly when detailed regional distributions are examined. Tabulations are provided to document these differences quantitatively. At scales below continental, the correlations observed between different model predictions are often very poor, particularly for land gridpoints during Northern Hemisphere (NH) summer, with differences of as much as 5° C between models and observations and between one model and another over relatively large areas.

A more limited analysis, using the results from only two GCMs, examines the seasonal variability of surface air temperature for the control climates. These results suggest that both models exhibit serious differences with historical climatology in at least one of the two meteorological seasons which are analyzed [December-January-February (DJF) or June-July-August (JJA)]. The implications of this work for investigation of climatic impacts on a regional scale are profound.

For these two very important variables, at least, the poor agreement between model simulations of the current climate on the regional scale calls into question the ability of these models to project the amplitude of future climatic change on anything approaching the scale of only a few (<10) gridpoints, which is essential if useful resource assessment studies are to be conducted. Much work remains to be done by the modeling community to better resolve the sources of disagreements among models and between models and observations so that model improvements can be made which will improve the climatic projections produced by these models. A stronger cooperative effort among the different modeling groups, including such recent initiatives as calculating results with a common set of boundary conditions, will be necessary so that we are sure that we are getting model agreement for the right reasons, a prerequisite for improving confidence in model projections.

**Surface Energy Balance of Three General Circulation Models:
Current Climate and Response to Increasing Atmospheric CO₂**
(DOE/ER-60422-H1, May 1988, 119 pp.)

TR042

W. J. Gutowski, D. S. Gutzler, D. Portman, and W.-C. Wang, Atmospheric and Environmental Research, Inc.

We examine the surface energy balance simulated by state-of-the-art general circulation models at GFDL, GISS and NCAR for climates with current levels of atmospheric CO₂ concentration (control climate) and with twice the current levels. The work is part of an effort sponsored by the U.S. Department of Energy to assess climate simulations produced by these models. The surface energy balance enables us to diagnose differences between models in surface temperature climatology and sensitivity to doubling CO₂ in terms of the processes that control surface temperature. Our analysis compares the simulated balances by averaging the fields of interest over a hierarchy of spatial domains ranging from the entire globe down to regions a few hundred kilometers across.

Principal Findings

1. For the global average control climate, individual surface fluxes of sensible heat (SH), latent heat (LH), shortwave radiation (SW) and upward (LW↑) and downward (LW↓) longwave radiation agree between the models to within 25 Wm⁻². In all three models the surface energy balance is dominated by longwave radiation (the "greenhouse" effect). Other surface fluxes are smaller, but the models also agree on their relative magnitudes. The 25 Wm⁻² difference is only a small fraction of the magnitudes of the largest fluxes, LW↓ and LW↑. However, the difference is a large fraction of the net longwave radiation at the surface (~60 Wm⁻²), and it is as large as any of the global-average seasonal changes in these fluxes. From this perspective, differences between surface fluxes in these state-of-the-art models are substantial even for the global average.
2. Global average changes in surface fluxes when CO₂ doubles agree between models to within 3 Wm⁻²; intermodel discrepancies are only small fractions of the flux changes from CO₂ doubling. However, the apparent agreement between models in Figure E-2 should be viewed with caution because flux changes associated with doubled CO₂ are about the same size as the differences between models in their control climates: 25 Wm⁻². Furthermore, averaging over the globe obscures much larger differences occurring on smaller scales (cf. points 4 and 6 below).

3. Spatial variation of net longwave radiation at the surface is small compared to the spatial variability of near-surface air temperature and moisture, both of which exert significant control on the new surface longwave flux. The relatively small variability of LW_{net} appears to be a consequence of compensation among variations of temperature, atmospheric moisture and clouds.
4. Intermodel differences in doubled- CO_2 surface flux changes of up to 100 Wm^{-2} occur near the limits of polar ice caps. Differences in ice modeling approach contribute strongly to the flux differences. Differences in control climate sea ice limits also help produce the strong differences in flux changes.
5. Differences between models for surface fluxes in regions a few hundred km across are often closely linked to differences in zonal mean climatology.
6. Intermodel surface flux discrepancies in the regional averages are as large as 50 Wm^{-2} , which is twice the difference found for the global average. Furthermore, models often disagree over the sign of regional flux changes when CO_2 doubles. Such differences appear to be closely associated with differences in model hydrology.
7. Fields that are subject to orographic control show relatively small intermodel discrepancy, i.e., differences between models for the same region tend to be smaller than interregional differences. A most notable example is precipitation, examined here because of its indirect relation to the surface energy balance through the hydrological cycle.

Recommendations

1. Effort should be given to developing a better understanding of the hydrological cycle and how to simulate it. Progress in this area appears to be especially important for improving regional climate modeling (point 6 above). Relatively large flux discrepancies on the global scale (points 1 and 2) may also be reduced by such progress because the hydrological cycle, through water vapor and cloud cover, strongly influences the longwave radiation transmitted from the atmosphere to the surface. Examples of the work needed are Manabe and Wetherald (1987) and Meehl and Washington (1987) who have analyzed soil moisture sensitivity in NCAR and GFDL model simulations of current and doubled CO_2 simulations.
2. Better agreement in zonal mean climatology between models is needed, since much of the intermodel difference in regional climatology is attributable to zonal mean differences between models.
3. Effects of increased resolution on regional simulation should be studied. Our results suggest that improvements in orographically dependent fields are possible simply by increasing resolution. Grid nesting needs to be explored as a means of improving regional modeling over land areas where orographic control may be important for regional climatology.

The Use of Statistical Climate-Crop Models for Simulating Yield to Project the Impacts of CO₂ Induced Climate Change
(DOE/ER/60444-H1, July 1988, 42 pp.)

TR043

W. L. Decker and R. Achutuni, University of Missouri-Columbia

Climate change has been projected to result from increased levels of greenhouse gasses. Obviously, significant changes in climate will influence agricultural production. Analysis techniques are needed to determine the consequences of climate change on agriculture production and food supply.

This report discusses (1) the historical perspective for the development of statistical models, (2) statistical models for assessing the impacts of CO₂-induced climate change, (3) production transformations resulting from climate change and CO₂ fertilization, (4) integration of direct effects of CO₂ fertilization with the indirect effects caused by climate change, and (5) the value of statistical modeling for estimating crop production for large areas having increased CO₂ concentrations.

The report recommends development in three areas important in modeling crop production: (1) a technique that results in a more reasonable adjustment than a fixed percentage increase by CO₂ fertilization and incorporates interactions between climate anomalies and CO₂ concentrations, (2) refinement of the relationship between yield and transpiration to provide a more rational approach to the estimation of production for large areas, and (3) comparison of estimations obtained from a process model and a statistical model for a large area (crop reporting district or state) and simulation of the variabilities of these two techniques using historical climatic records.

Documentation of IAP Two-Level Atmospheric General Circulation Model

TR044

(DOE/ER/60314-H1, February 1989, 383 pp.)

Q.-C. Zeng, X.-H. Zhang, X.-Z. Liang, C.-G. Yuan, and S.-F. Chen, Institute of Atmospheric Physics, Beijing, People's Republic of China

Since 1980, a group directed by Qing-Cun Zeng at the Institute of Atmospheric Physics (IAP) of the Chinese Academy of Science has been developing grid-point general circulation models (GCMs) for climate simulations. Unique characteristics make the dynamic framework of the models different from other GCMs.

1. Departures of temperature, geopotential, and surface pressure from their "standards" are introduced to cancel the large truncation errors in the mountain regions.
2. New coordinates and variables are introduced, leading the energy equation to a very compact form and the grid to a more flexible arrangement.
3. The computation scheme conserves the "available" energy conservation exactly (if the dissipation is omitted), and is free from computational modes.
4. No false source exists because the formulation and calculation of boundary terms or boundary conditions at the atmosphere-ocean and atmosphere-land interfaces are physically consistent.

Taking these characteristics into consideration, the authors have designed several schemes using spherical grids. One of the schemes, on C-grid system, was first designed and reported by Zeng and then extended to the atmosphere-ocean-coupled model. Most recently the authors also designed a B-grid scheme. Both schemes conserve the "available" energy of dissipative and adiabatic atmosphere under the "standard stratification approximation" or provide a bounded norm of the predicted variables in L_2 space if the implicit and split methods are applied, without using the standard stratification approximation. The B-grid scheme is used to compute wind vector directly at gridpoints, without using interpolations of wind components, and can easily be used in conjunction with implicit or semi-implicit methods. However, the C-grid scheme is economical in computation and suitable to stepwise topography. It is this scheme that has been thoroughly and systematically tested and applied to climate simulations. Based upon the C-grid scheme, a two-level global atmospheric GCM (AGCM) and a four-level world ocean GCM (OGCM) have been completed with $4^\circ \times 5^\circ$ horizontal resolution and have been applied to climate simulations. The report documents the control version of the IAP two-level AGCM.

The physical parameterization schemes such as longwave radiation, cloud prediction, convective processes, boundary layer treatment and the ground surface hydrology developed by OSU are adopted with appropriate modifications in the current version of IAP two-level AGCM. However, in IAP AGCM, some nonlinear horizontal diffusion is included and the solar radiation is calculated using the delta-Eddington model, which accommodates the inclusion of atmospheric smoke and dust in addition to atmospheric Rayleigh scattering and absorptions of ozone and water vapor. The IAP AGCM emphasizes the prediction of water vapor transport because the condensation process is extremely important not only in causing precipitation, which is a main variable characterizing the regional climate, but also in controlling the internal energy source in atmospheric motions. The scheme presented can avoid drastic variations in water vapor distribution.

A full presentation of the model's dynamic framework; the calculations of the physics (source and sink terms) and treatment of boundary conditions; the FORTRAN program, including a directory of purpose, algorithm, and IO information for each subprogram; the FORTRAN symbols in the named common blocks, together with a brief description or definition, the mathematical equivalent, the units, and location in the code listing; a physics dictionary summarizing the treatment of numerous variables and giving their location in the code and references; and a guide to model use and operation, including a complete collection of IO information in a model integration are included.

TR045 A Preliminary Analysis of U.S. CO₂ Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010
(DOE/NBB-0085, February 1989, 56 pp.)

J. A. Edmonds and W. B. Ashton, Pacific Northwest Laboratory

H. C. Cheng and M. Steinberg, Brookhaven National Laboratory

This report sheds light on the issue of U.S. CO₂ emissions reduction potential from the present to the year 2010 from energy conservation and the substitution of natural gas for coal. A preliminary assessment of the technical feasibility and consequences of reducing U.S. CO₂ emissions from 1985 levels by 10, 25, or 50% by either the year 1995 or 2010. Conservation potential studies were also examined to see what energy and conservation efficiency improvements are feasible at current and anticipated energy technologies and prices.

**Global Lake-Level Variations from 18,000 to 0 Years Ago: A
Palaeoclimatic Analysis**

TR046

(DOE/ER/60304-H1, September 1989, 213 pp.)

F. A. Street-Perrott, D. S. Marchand, N. Roberts, and S. P. Harrison, Oxford University

Fluctuations in the water levels of lakes can be an important source of information about past climates and can be used to validate the palaeoclimatic simulations made with atmospheric general-circulation models. The Oxford Lake-Level Data Bank contains information about variations in the water levels of about 360 lake basins during the past 30,000 years. This data set was compiled as part of the Climates of the Holocene Mapping Project (COHMAP). In this report, regional and global maps of lake status (coded as high, intermediate, or low) at 18, 15, 12, 9, 6, 3, and 0 thousands of years Before Present are presented and compared with numerical simulations for the same time slices carried out with the National Center for Atmospheric Research (NCAR) Community Climate Model. Although agreement between the data and the model is generally excellent, significant discrepancies occur. These may reflect the effects of changes in boundary conditions that were not included in the experiments, for example increased glacial-age aerosol loadings, as well as the inability of the model to portray some of the complexities of the climate system such as oceanic circulation and orographic effects.

**An Evaluation of the Relationship Between the Production and Use
of Energy and Atmospheric Methane Emissions**

TR047

(DOE/NBB-0088P, April 1990, 234 pp.)

D. W. Barns and J. A. Edmonds, Pacific Northwest Laboratory

Methane is the most abundant hydrocarbon in the atmosphere. It has an assumed lifetime of about 10 years, and its atmospheric concentration is increasing about 1% per year. It is also one of the most potent of the greenhouse gases, with more than 30 times the warming potential of carbon dioxide on a per molecule basis.

Much of the atmosphere's methane comes from natural sources like wetlands. But a significant portion comes from human activities; probably 20 to 30% of the overall total comes from the production, distribution, and use of energy. Unlike carbon dioxide, only a small fraction of the methane in the atmosphere is produced by combustion. Rather, it comes from coal mining, natural gas production and distribution, automotive exhausts, biomass burning, and landfill decay. Moreover, the quantitative relationships are much more ambiguous with methane than they are with carbon dioxide.

Those relationships were estimated and emission coefficients were determined to extend the Edmonds-Reilly Long-Term Energy-CO₂ Model to include the effects of methane emissions. This report discusses the sources of information on emissions, the difficulties in assessing coefficients, and the final values chosen for the expanded model.

Methane emissions from coal mining are essentially a function of coal rank and depth; a weighted average of 250 cubic feet per short ton of production was used. Natural gas is mostly methane, and a 2% loss to the atmosphere was assessed. Venting and flaring data are available for most countries, but much of that data is of questionable accuracy, so the fraction vented was assessed at one-fifth. The range of methane emissions from automobiles and trucks is very wide; the global total emission was estimated to be 1 to 2 teragrams per year (Tg/y). Traditional biomass (fuel

wood and bagasse) burning was estimated to introduce 10 to 15 Tg/y into the air. Finally, landfill emissions were estimated to contribute 30 to 70 Tg/y to the atmosphere.

These estimated methane emissions total about 110 Tg/y. In comparison with similar studies, this value is in the low end of the range. Use of these values in the model, therefore, provides an element of conservatism.

TR048 Effects of Air Temperature on Atmospheric CO₂-Plant Growth Relationships

(DOE/ER-0450T, April 1990, 61 pp.)

S. G. Allen, S. B. Idso, and B. A. Kimball, U.S. Water Conservation Laboratory

J. T. Baker and L. H. Allen, Jr., SDA-ARS and the University of Florida

J. R. Mauney and J. W. Radin, Western Cotton Research Laboratory

M. G. Anderson, Arizona State University

In general, doubling the concentration of atmospheric CO₂ increases the productivity of C3 plants by about one-third. Because temperature may influence this effect, the literature on this topic was searched and is summarized in this report.

The enhancement in plant growth and photosynthesis of C3 species brought about by greater CO₂ concentration increases with air temperature. Increased temperature and a doubling of CO₂ concentration produced a maximum increase in growth of 300% and in net photosynthesis of 170% in C3 plants. The interaction between temperature and CO₂ concentration differs considerably among species. This interspecies variation may explain much of the wide range in plant responses to CO₂ concentration reported in the literature. Crop species' responses to increased CO₂ concentration and temperature should therefore be studied individually. In addition, CO₂ concentration appears to interact with other climatic variables, such as solar radiation, in its effect on plant productivity. Growth and productivity effects are nowhere near as pronounced with C4 species as they are with C3 species because of the more efficient photosynthetic mechanism of C4 plants.

Stomatal conductance of C4 species did, however, respond to combined increases in CO₂ concentration and temperature; the decrease in stomatal conductance produced by enriched CO₂ was enhanced by increasing temperature. As a result, a significant increase in water-use efficiency of C4 crops can be expected in a high-CO₂ environment.

TR049 Simulating Climate With Two Different Numerical Schemes

(DOE/34-0459T, June 1990, 57 pp.)

W. J. Gutowski and M. J. Iacono, Atmospheric and Environmental Research, Inc.

Xin-Zhong Liang, State University of New York, Stony Brook

Wei-Chyung Wang, State University of New York, Albany

To determine the dependence of climate simulation on model numerics, two simulations of a perpetual July were run on the Oregon State University two-layer atmospheric-physics model, one

that used gridpoint techniques for the numeric treatment of atmospheric dynamics and one that used spectral techniques.

The gridpoint model produced a stronger circulation. The differences in atmospheric transport predicted by the two models have a significant influence on the atmospheric portion of the hydrologic cycle. The gridpoint model produces more frequent precipitation, especially in the tropics, and higher amounts of atmospheric moisture. Consequently, it indicates greater cloud cover, producing differences in other fluxes, such as solar and terrestrial radiation. Substantial regional differences in the models' simulations were found, but differences in zonal averages typically dominate differences appearing in spatial distributions of climatological fields.

Removing certain feedbacks in the climate system underscored the differences produced by the choice of numeric technique. For example, diabatic heating tends to amplify differences resulting from the choice. Varying horizontal resolution also alters the model climatology. To a certain degree, these differences are tempered when a model is tuned to account for and reflect current climate. However, the choice of numeric technique should be made carefully because it may still influence a model's sensitivity to forcing changes.

Modeling pCO₂ in the Upper Ocean: A Review of Relevant Physical, Chemical, and Biological Processes (DOE/RL-01830T-H5, December 1990, 63 pp.)

TR050

D. Archer, University of Washington

The pCO₂ of the surface ocean is controlled by a combination of physical, chemical, and biological processes. Modeling surface ocean pCO₂ is analogous to modeling sea surface temperature (SST), in that sea surface pCO₂ is affected by fluxes across the air-sea interface and by exchange with deeper water. However, pCO₂ is also affected by chemical and biological processes which have no analog in SST. Seawater pCO₂ is buffered by pH equilibrium reactions between the species CO₂, HCO₃⁻, and CO₃⁼. This effect provides an effective reservoir for CO₂ in seawater that is 10 times larger than it would be for an unbuffered gas. The equilibrium between dissolved and atmospheric CO₂ is sensitive to temperature, tending to higher pCO₂ in warmer water.

Biological export of carbon as sinking particles maintains a gradient of pCO₂, with lower values near the surface (this process is called the "biological pump"). In most of the ocean, biological activity removes all of the available nutrients from the surface water; that is, the rate of carbon export in these locations is limited by the rate of nutrient supply to the euphotic zone. However, in much of the high-latitude oceans, primary production does not deplete the euphotic zone of nutrients, a fact to which the atmospheric pCO₂ is extraordinarily sensitive. Understanding the limits to phytoplankton growth in the high latitudes, and how these limits might change under different climatic regimes, is essential to prediction of future ocean uptake of fossil fuel CO₂.

Because many of the processes controlling sea surface pCO₂ are driven by mixing in the upper ocean, fluctuations in the depth of the mixed layer are of primary importance to modeling sea surface pCO₂. The depth of the mixed layer can be predicted using a numerical model of the upper ocean. Fluxes of heat, momentum, and dissolved gases provide the boundary conditions for such a model. A major limitation on the precision of calculated heat fluxes is the effect of clouds on the atmospheric radiative heat fluxes.

Three families of mixed layer models have been developed, and although the physical mechanisms by which mixing occurs differ among the model groups, all are successful at predicting the observed ocean mixed layer depth. The "integrated turbulent kinetic energy" (TKE) models construct a budget for surface ocean TKE, using the wind stress as source and dissipation as sink for TKE. Excess kinetic energy is converted to potential energy by mixing denser water up into the surface mixed layer. The "shear instability" models maintain profiles of current velocity resulting from the wind stress; when the current shear becomes too large relative to density stratification, the model mixes (entrains) deep water into the surface layer. "Turbulence closure" models are the most general and the most complicated of the three types, and are based on laboratory studies of fluid turbulence. This paper explores behavioral distinctions between the three types of models, and summarizes previously published comparisons of the generality, accuracy, and computational requirements of the three models. The application of mixed layer models to treatment of sea ice is also reviewed.

Simulation of the upper ocean on a global scale is limited by finite computation resources and by imperfect meteorological forcing data. The air-sea heat fluxes can either be calculated as described above or imposed using an "SST restoring" strategy which pushes the model SST toward observations within some relaxation time constant. Simulation of free convection driven by surface cooling, particularly deep convection in high-latitude winter, is essential to modeling formation of deep water and is therefore an integral part of virtually all circulation models. Convection driven by the wind (forced convection) requires higher spatial resolution and more detailed meteorological forcing data. One strategy for reducing overhead associated with the mixed layer is to "embed" the mixed layer into a surface box of variable thickness, within a deeper surface box. All three mixed layer model types have been incorporated into global-scale simulations.

TR051 A Comprehensive Precipitation Data Set for Global Land Areas
(DOE/ER-69017T-H1, April 1991, 82 pp.)

J. K. Eischeid and H. F. Diaz, NOAA/ERL

R. S. Bradley, University of Massachusetts

P. D. Jones, University of East Anglia

An expanded and updated compilation of long-term station precipitation data, together with a new set of gridded monthly mean fields for global land areas, are described. The present data set contains 5328 station records of monthly total precipitation, covering the period from the mid-1800s to the late 1980s. The station data were individually tested and visually inspected for the presence of spurious trends, jumps, and other measurement biases. The quality control procedure which was used to check the station records for nonclimatic discontinuities and other biases is detailed. We also discuss some of the problems which typically contribute to potential inhomogeneities in precipitation records.

The station data were interpolated onto a 4° latitude by 5° longitude uniform grid. Comparisons of these data with two other global-scale precipitation climatologies are presented. We find good agreement among the three global-scale climatologies over the common areas in each set. Three different indices of long-term precipitation variations over the global land areas all indicate a general increase of annual precipitation since the 1940s, although a decline is evident over the last decade. There is some indication that the last few decades of the 19th century may have been as wet as the recent ones. An interesting feature of this study is the presence of relatively large differences in seasonal trends, with March–May and September–November becoming wetter in the last few decades. The December–February and June–August seasons exhibit smaller overall trends, although the northern winter season does exhibit large decadal-scale fluctuations.

A Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. An Overview

TR052

(DOE/RL/01830T-H5, August 1991, 35 pp.)

N. J. Rosenberg and P. R. Crosson, Resources for the Future, Washington, D.C.

This overview report explains the rationale for and the methodology used in conduct of the study "Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project," commissioned by the U.S. Department of Energy. The major findings of the study are also presented in this overview, which accompanies a series of six reports in which the requisite technical details on methodology, sectoral analyses, and integrated analysis of climate change impacts and responses are provided in detail.

Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report I. Background and Baselines

TR052B

(DOE/RL/01830T-H6, August 1991, 113 pp.)

N. J. Rosenberg, P. R. Crosson, K. D. Frederick, W. E. Easterling, III, M. S. McKenney, R. A. Sedjo, M. D. Bowes, J. Darmstadter, L. A. Katz, and K. M. Lemon, Resources for the Future, Washington, D.C.

This report (No. 1) is intended to provide background information on project organization and methodology (Sec. 1). In Sec. 2 and 3 the region chosen for study and the scenario of climate change applied to it are described. The remainder of the paper provides information on the current functioning of the region—its demography and macroeconomic characteristics, its major natural resource sectors, the way these sectors interlink among themselves and with other industries and the region's economic base. In the final section projections are made of the demographics and macroeconomic characteristics of the region 20 and 40 years into the future.

Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IIA. Agricultural Production and Resource Use in the MINK Region Without and With Climate Change

TR052C

(DOE/RL/01830T-H7, August 1991, 123 pp.)

P. R. Crosson, L. A. Katz, and J. Wingard, Resources for the Future, Washington, D.C.

This report (IIA) treats agriculture in MINK in terms of state and region-wide production and resource use for the main crops and animals in the baseline periods of 1984–87 and 2030. The effects of the analog climate on the industry at this level of aggregation are considered in both baseline periods.

TR052D Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IIB. A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region
(DOE/RL/01830T-H8, August 1991, 222 pp.)

W. E. Easterling, III, M. S. McKenney, N. J. Rosenberg, and K. M. Lemon,
Resources for the Future, Washington, D.C.

This report (IIB) deals with agriculture at the level of farms and Major Land Resource Areas (MLRAs). The Erosion Productivity Impact Calculator (EPIC), a crop growth simulation model developed by scientists at the U.S. Department of Agriculture, is used to study the impacts of the analog climate on yields of main crops in both the 1984–87 and the 2030 baselines. The results of this work with EPIC are the basis for the analysis of the climate change impacts on agriculture at the region-wide level undertaken in the report.

TR052E Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report III. Forest Resources
(DOE/RL/01830T-H9, August 1991, 123 pp.)

M. D. Bowes and R. A. Sedjo, Resources for the Future, Washington, D.C.

This report is directed to an analysis of the possible impacts of climatic change on forest resources in the Missouri-Iowa-Nebraska-Kansas region. It follows a uniform methodological strategy that is applied to the four resource sectors most likely to be impacted by climate change (i.e., agriculture, forestry, water resources, and energy). The methodological strategy is fully explained in report I of this series.

TR052F Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IV. Water Resources
(DOE/RL/01830T-H10, August 1991, 153 pp.)

K. D. Frederick, Resources for the Future, Washington, D.C.

This report is directed to an analysis of the possible impacts of climatic change on water resources in the Missouri-Iowa-Nebraska-Kansas region. It follows a uniform methodological strategy that is applied to the four resource sectors most likely to be impacted by climate change (i.e., agriculture, forestry, water resources, and energy). The methodological strategy is fully explained in report I of this series.

Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report V. Energy

TR052G

(DOE/RL/01830T-H11, August 1991, 60 pp.)

J. Darmstadter, Resources for the Future, Washington, D.C.

This report is directed to an analysis of the possible impacts of climatic change on energy in the Missouri-Iowa-Nebraska-Kansas region. It follows a uniform methodological strategy that is applied to the four resource sectors most likely to be impacted by climate change (i.e., agriculture, forestry, water resources, and energy). The methodological strategy is fully explained in report I of this series.

Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report VI. Consequences of Climate Change for the MINK Economy: Impacts and Responses

TR052H

(DOE/RL/01830T-H12, August 1991, 58 pp.)

M. D. Bowes and P. R. Crosson, Resources for the Future, Washington, D.C.

This report is directed to providing an integrated analysis of the possible economic impacts of climatic change on resources in the Missouri-Iowa-Nebraska-Kansas region. It is based on a uniform methodological strategy that was applied to the four resource sectors most likely to be impacted by climate change (i.e., agriculture, forestry, water resources, and energy). The methodological strategy is fully explained in report I of this series.

The Determination of Total Dissolved Inorganic Carbon in Sea Water Using Extraction/Coulometry: The First Stage of a Collaborative Study

TR053

(DOE/RL/01830T-H14, February 1992, 43 pp.)

A. G. Dickson, Scripps Institution of Oceanography

Samples of sterilized sea water were bottled and sent to a total of fifteen laboratories for analysis for total dissolved inorganic carbon. These were located in Canada (2), Germany (1), The Netherlands (1), Sweden (1), the United States (9), and the United Kingdom (1). All except one laboratory used their current implementation of an extraction/coulometric procedure to analyze the samples; the other laboratory, Dr. Keeling's laboratory at the Scripps Institution of Oceanography, analyzed the samples using their extraction/manometric procedure, which is considered a "definitive" method.

Each of the laboratories returned at least some results, and only two laboratories were clearly (on their own admission) having substantial difficulties in implementing the procedure. The results from the other twelve laboratories were extremely encouraging. The within-laboratory standard deviation of the results reported by the various laboratories (omitting the two that had substantial difficulties) ranged from 0.56–2.75 $\mu\text{mol}\cdot\text{kg}^{-1}$ with a pooled standard deviation of 1.55 $\mu\text{mol}\cdot\text{kg}^{-1}$. The weighted mean calculated from the results of these twelve laboratories was 1977.8 $\mu\text{mol}\cdot\text{kg}^{-1}$; almost identical to the certified value obtained by extraction/manometry (1978.8 $\mu\text{mol}\cdot\text{kg}^{-1}$). This

indicates that the extraction/coulometric procedure is capable of making unbiased measurements. Unfortunately, the spread of the mean values from these twelve laboratories was substantial ($17.2 \mu\text{mol}\cdot\text{kg}^{-1}$) and only five sets of results had a mean that was equivalent to the certified value (with 95% confidence).

Although the optimal procedure for this determination is still not clear (some recommendations for further study are contained in the body of this report), I believe the majority of these discrepancies results from the lack (at the time of this study) of a written standard operating procedure and of certified reference materials for total dissolved inorganic carbon in sea water.

This is no longer the case; both now exist and it remains to see if the expected improvements materialize. In April 1992, I intend to initiate a further study distributing blind samples to various laboratories for analysis to assess what, if any, changes have taken place.

TR054 Modeling the Response of Plants and Ecosystems to Elevated CO₂ and Climate Change
(DOE/ER-60490T-H1, March 1992, 190 pp.)

J. F. Reynolds, D. W. Hilbert, J. Chen, P. C. Harley, P. R. Kemp, and P. W. Leadley,
San Diego State University

In recognition of the role of plants in the bio-geosphere carbon cycle, the Carbon Dioxide Research Program of U.S./DOE initiated a research program on the Direct Effects of Increasing Carbon Dioxide on Vegetation (Stain and Cure 1985; Dahlman 1985). This report describes continuing research that we are conducting as part of the DOE/CO₂ program to develop a general ecosystem model to investigate the potential responses of different terrestrial ecosystems to changes in the global environment over the next century. The Committee on Global Change (1988) notes that such "generic ecosystem models" can only be useful for predicting responses of ecosystems to future global changes if they are linked to population-community models. Our research approach incorporates such efforts as part of a multi-investigator, multi-university, long-term research strategy developed with the ultimate goal of providing experimental data, modeling methodology, and models for predicting long-term, large-scale ecosystem response to global change.

TR055 Climate Data Bases of the People's Republic of China 1841-1988
(DOE/NBB-0091T, January 1993, 215 pp.)

D. Kaiser, University of Tennessee and Oak Ridge National Laboratory

S. Tao, C. Fu, Z. Zeng, and Q. Zhang, Chinese Academy of Sciences

W.-C. Wang, State University of New York, Albany

T. Karl, National Climatic Data Center

A data base containing meteorological observations from the People's Republic of China (PRC) is described. These data were compiled in accordance with a joint research agreement signed by the U.S. Department of Energy and the PRC Chinese Academy of Sciences (CAS) on August 19, 1987. CAS's Institute of Atmospheric Physics (Beijing, PRC) has provided records from 296 stations, organized

into five data sets: (1) a 60-station data set containing monthly measurements of barometric pressure, surface air temperature, precipitation amount, relative humidity, sunshine duration, cloud amount, wind direction and speed, and number of days with snow cover; (2) a 205-station data set containing monthly mean temperatures and monthly precipitation totals; (3) a 40-station subset of the 205-station data set containing monthly mean maximum and minimum temperatures and monthly extreme maximum and minimum temperatures; (4) a 180-station data set containing daily precipitation totals; and (5) a 470-station data set containing 10-day precipitation totals. Sixteen stations from these data sets (13 from the 60-station set and 3 from the 205-station set) have temperature and/or precipitation records that begin prior to 1900, whereas the remaining stations began observing in the early to mid-1900s. Records from most stations extend through 1988.

These data can be used in defining regional climate changes, establishing relationships between regional and large-scale climates, studying the climatic impacts of urbanization and increased concentrations of greenhouse gases, and assembling large-scale climate data bases. Additional uses could include examining impacts of periodic events such as volcanic eruptions or the El Niño/Southern Oscillation. These data sets represent the most comprehensive, long-term instrumental Chinese climate data currently available.

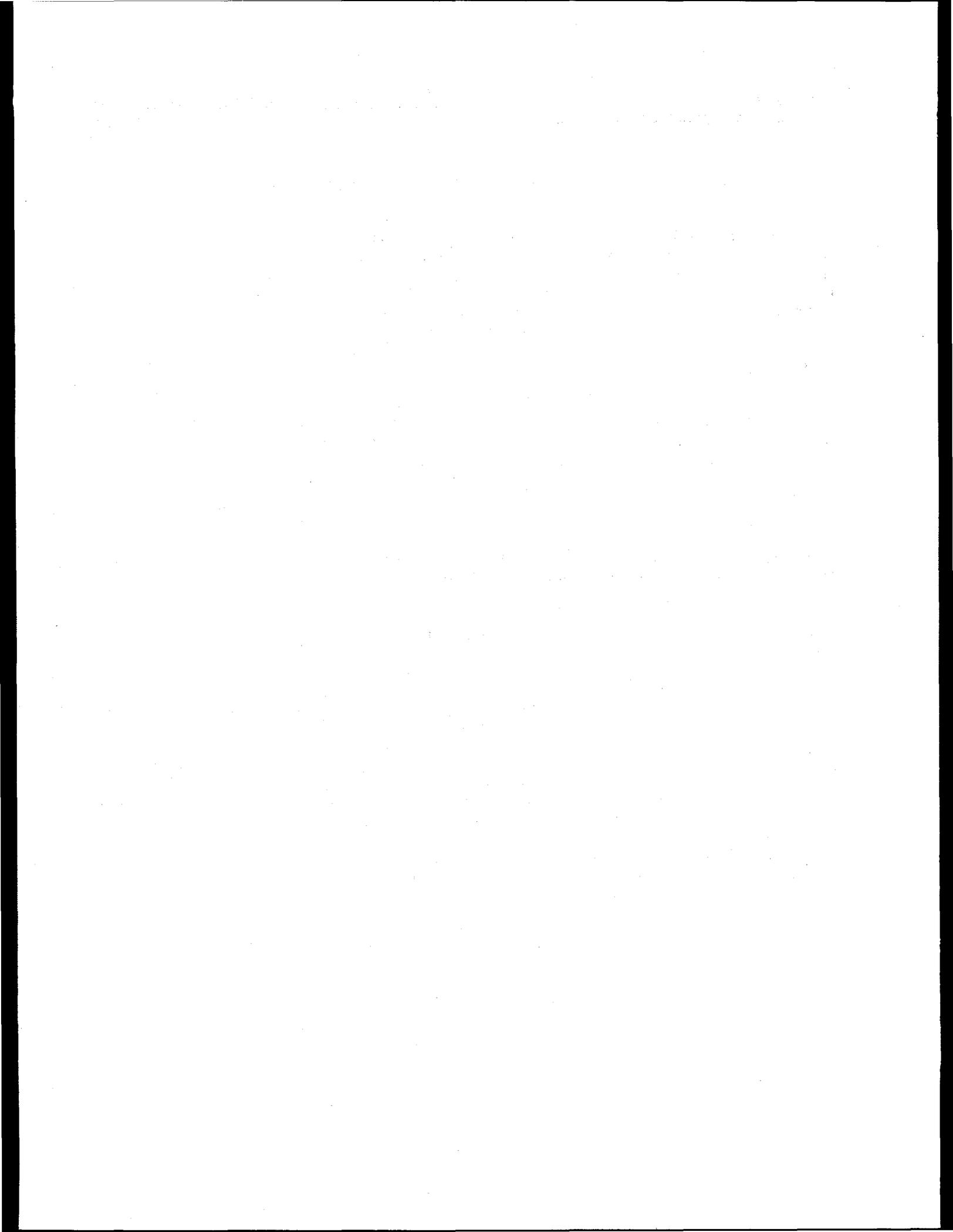
Photosynthesis, Environmental Change, and Plant Adaptation— Research Topics in Plant Molecular Ecology

TR056

(DOE/NBB-0093T, July 1995, 37 pp.)

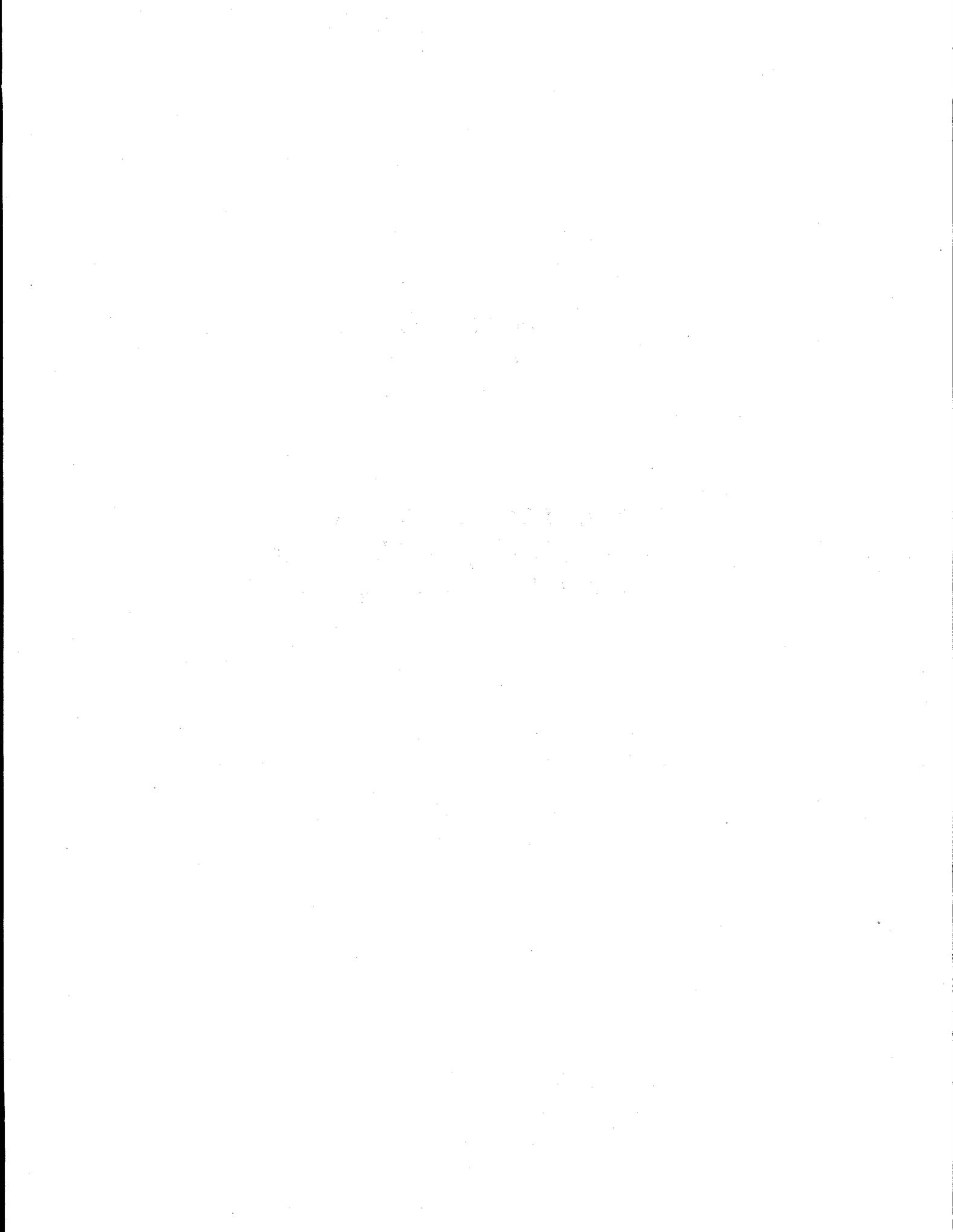
**Office of Health and Environmental Research and Office of Basic Energy Sciences,
U.S. Department of Energy**

In October 1993, a group of more than 20 scientists, representing various areas of expertise related to ecology and photosynthesis, met to identify key scientific questions and possible experimental approaches to understanding the responses of photosynthetic organisms to global climate change. The rationale for this workshop was a need to develop a mechanistic understanding of photosynthetic responses to environmental changes at local, regional, and global levels. The workshop provided a forum for interdisciplinary scientific discussion on the productivity and photosynthetic responses of terrestrial and oceanic plants. Potential research topics were discussed to try to integrate molecular and biophysical methods with ecosystem-response studies. Only such a comprehensive research approach can provide the scientific information on photosynthetic organisms, related biotechnologies information on photosynthetic organisms, and related biotechnologies needed to evaluate biologically based alternative energy-supply options.



Section C

U.S. Department of Energy Atmospheric Radiation Measurements (ARM) Program Reports



Atmospheric Radiation Measurement Program Plan

(February 1990)

DOE/ER-
0441**Atmospheric and Climate Research Division, U.S. Department of Energy**

Scientists from the DOE National Laboratory community contributed to the preparation of the ARM Program Plan with input from members of the academic community, the private sector, and from scientists from other Committee on Earth Sciences (CES) agencies. The Plan was subjected to an extensive peer review and the many helpful comments we have received have been incorporated into this document. We believe that ARM will serve the CES objectives in Global Change research and support the DOE mission of formulating a National Energy Strategy that takes into account the potential for global climate change.

Atmospheric Radiation Measurement Program Plan, Executive Summary

(February 1990)

DOE/ER-
0442**Atmospheric and Climate Research Division, U.S. Department of Energy**

Scientists from the DOE National Laboratory community contributed to the preparation of the ARM Program Plan with input from members of the academic community, the private sector, and from scientists from other Committee on Earth Sciences (CES) agencies. The Plan was subjected to an extensive peer review and the many helpful comments we have received have been incorporated into this document. We believe that ARM will serve the CES objectives in Global Change research and support the DOE mission of formulating a National Energy Strategy that takes into account the potential for global climate change.

Identification, Recommendation, and Justification of Potential Locales for ARM Sites, Executive Summary

(April 1991)

DOE/ER-
0494T**Atmospheric and Climate Research Division, U.S. Department of Energy**

This report is an account of a study that was undertaken within the ARM program to examine locations suitable for establishing and maintaining experimental sites that meet the objectives of ARM and to recommend an ordered set of locales in which to locate sites, thereby creating the framework for site selection. Selection of specific ARM sites will come from further analysis based on the principles established in this report. The results of the study have been reviewed by several entities within the ARM program and DOE, as well as leading scientists in the meteorological and atmospheric radiation community. This report incorporates the many helpful comments and suggested changes received from these reviews.

**DOE/ER-
0495T**

**Identification, Recommendation, and Justification of Potential
Locales for ARM Sites**
(April 1991)

Atmospheric and Climate Research Division, U.S. Department of Energy

This report is an account of a study that was undertaken within the ARM program to examine locations suitable for establishing and maintaining experimental sites that meet the objectives of ARM and to recommend an ordered set of locales in which to locate sites, thereby creating the framework for site selection. Selection of specific ARM sites will come from further analysis based on the principles established in this report. The results of the study have been reviewed by several entities within the ARM program and DOE, as well as leading scientists in the meteorological and atmospheric radiation community. This report incorporates the many helpful comments and suggested changes received from these reviews.

**DOE/ER-
0585T**

**The Possible Direct Use of Satellite Radiance Measurements
by the Atmospheric Radiation Measurement Program**
(March 1993)

Environmental Sciences Division, U.S. Department of Energy

The Atmospheric Radiation Measurement (ARM) Program is a major research program initiated by the U.S. Department of Energy to improve scientific understanding of radiative and cloud processes critical to predicting the Earth's climate and future climate changes. Central to this concept is the use of four to six intensively instrumented sites for long-term study and characterization of the processes of interest. The instrumentation sites will include ground-based, high-accuracy radiometers for measuring the short and longwave surface flux, as well as an extensive set of ground- and air-based instrumentation for characterizing the intervening atmospheric column. Satellite-based measurements are expected to play a very important role in providing top-of-atmosphere (TOA) measurements.

In an earlier study, we assessed the current and planned satellite measurement capabilities as they relate to ARM. That study focused on the ability of satellites to provide such derived physical quantities as temperature and water-vapor profiles; cloud coverage, top height, and temperature; and earth radiation budgets. Although such derived products can be very useful, they often involve significant processing of the direct satellite data (e.g., inversion of radiance to obtain temperature and water-vapor profiles or the conversion of radiances to fluxes to obtain radiation budgets). This processing in turn often requires both modeling and auxiliary data sets (e.g., initial-guess profiles for the inversion). Thus, unless great care is taken, there is a very real danger that such "derived" satellite data would not be an independent data set against which to compare ARM outputs.

In this study, we examine the possibility of comparing ARM outputs directly with satellite measurements, thereby ensuring the independence of these two important data sets. Thus, we have focused on four questions: (1) What do satellites really measure and how well do they measure it? (2) What can we do about the general lack of adequate visible channel calibration? (3) What is the best way for ARM to obtain near-real-time access to this unprocessed data?

(4) What is the optimum way for ARM to make use of satellite data? The answer to each of these questions is summarized in the detailed papers that follow.

**Science Plan for the Atmospheric Radiation Measurement Program
(ARM)
(February 1996)**

**DOE/ER-
0670T**

Environmental Sciences Division, U.S. Department of Energy

The purpose of this Atmospheric Radiation Measurement (ARM) Science Plan is to articulate the scientific issues driving the ARM Program, and to relate them to DOE's programmatic objectives for ARM, based on the experience and scientific progress gained over the past five years.

**Proceedings of the Second Atmospheric Radiation Measurement
(ARM) Science Team Meeting
(December 1992)**

**CONF-
9110336**

Environmental Sciences Division, U.S. Department of Energy

The second Atmospheric Radiation Measurement (ARM) Science Team Meeting was held in Denver, Colorado, in October 1991. The 5 day meeting provided a forum for a technical exchange among the members of the ARM Science Team and a discussion of the technical aspects of the project infrastructure. The meeting included several activities: Science Team presentations, discussions of the first site occupation plan, experiment design sessions, and poster sessions. This proceedings document includes papers presented at the meeting. The papers included are those from the technical sessions, the experiment design sessions, the first site occupation, and descriptions of locales for future sites.

**Proceedings of the Third Atmospheric Radiation Measurement
(ARM) Science Team Meeting
(March 1994)**

**CONF-
9303112**

Environmental Sciences Division, U.S. Department of Energy

The Third Atmospheric Radiation Measurement (ARM) Science Team Meeting was held in Norman, Oklahoma, in March 1993. This proceedings document includes papers presented at the meeting.

**Proceedings of the Fourth Atmospheric Radiation Measurement
(ARM) Science Team Meeting
(April 1995)**

**CONF-
940277**

Environmental Sciences Division, U.S. Department of Energy

The Fourth Atmospheric Radiation Measurement (ARM) Science Team Meeting was held in Charleston, South Carolina, from February 18– March 3, 1994. This proceedings document includes papers presented at the meeting.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that this is crucial for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and tools used to collect and analyze data. It highlights the need for consistent and reliable data collection processes to support effective decision-making.

3. The third part of the document focuses on the role of technology in data management and analysis. It discusses how modern software solutions can streamline data collection, storage, and reporting, thereby improving efficiency and accuracy.

4. The fourth part of the document addresses the challenges associated with data management, such as data quality, security, and privacy. It provides strategies to mitigate these risks and ensure that data is used responsibly and ethically.

5. The fifth part of the document discusses the importance of data governance and the role of leadership in establishing a strong data culture. It emphasizes that data should be treated as a valuable asset that requires careful management and oversight.

6. The sixth part of the document explores the various applications of data analysis in different industries and sectors. It provides examples of how data-driven insights can be used to optimize performance, identify trends, and make strategic decisions.

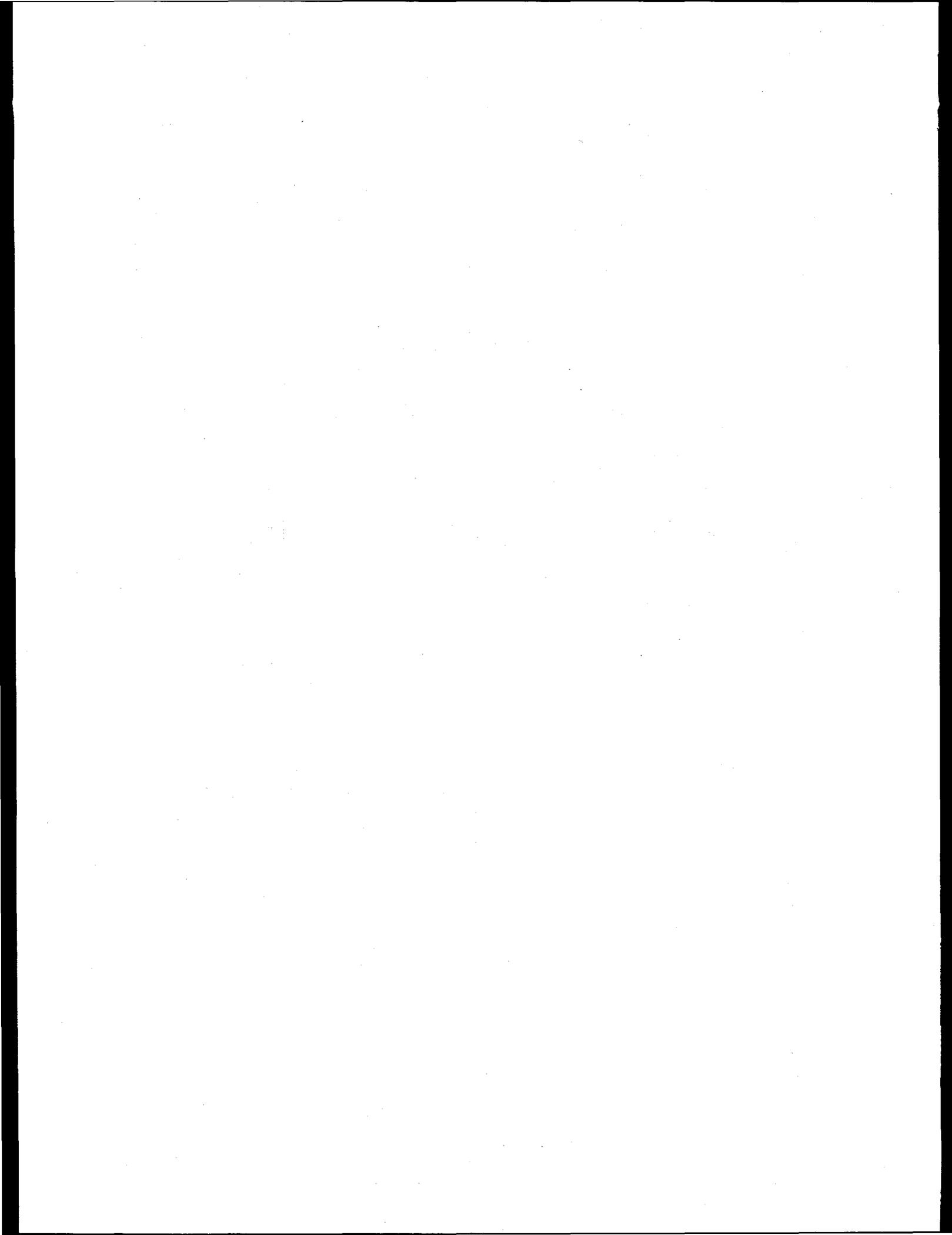
7. The seventh part of the document discusses the future of data management and analysis, including emerging technologies like artificial intelligence and machine learning. It highlights the potential for these technologies to revolutionize data-driven decision-making.

8. The eighth part of the document provides a summary of the key points discussed throughout the document. It reiterates the importance of data in driving organizational success and the need for a comprehensive data management strategy.

9. The final part of the document offers concluding thoughts and recommendations for organizations looking to improve their data management practices. It encourages a proactive approach to data management and a commitment to continuous improvement.

Section D

Other U.S. Department of Energy Reports



Four State-of-the-Art (SOA) volumes document what is known, unknown, and uncertain about CO₂ data, analyses, and modeling capabilities. They also outline potential avenues of research for reducing critical uncertainties. The four volumes are:

Detecting the Climatic Effects of Increasing Carbon Dioxide
(December 1985)

DOE/ER-
0235

M. C. MacCracken and F. M. Luther (eds.), Lawrence Livermore National Laboratory

The objective of this volume is to document what is known about detecting the CO₂-induced changes in climate and to describe the uncertainties and unknowns associated with this monitoring and analysis effort.

Characterization of Information Requirements for Studies of CO₂ Effects: Water Resources, Agriculture, Fisheries, Forests and Human Health
(December 1985)

DOE/ER-
0236

M. R. White, Lawrence Berkeley Laboratory

This companion volume to the SOAs establishes a baseline of knowns and unknowns and delineates the data and improvements in methodology required to estimate the impacts on humankind from increased atmospheric CO₂.

Projecting the Climatic Effects of Increasing Carbon Dioxide
(December 1985)

DOE/ER-
0237

M. C. MacCracken and F. M. Luther (eds.), Lawrence Livermore National Laboratory

This volume summarizes what is known about projections of the climatic effects of the increasing CO₂ concentration and describes the uncertainties and unknowns associated with such projections.

Direct Effects of Increasing Carbon Dioxide on Vegetation
(December 1985)

DOE/ER-
0238

B. R. Strain and J. D. Cure (eds.), Duke University

This volume summarizes the current knowledge of the direct effects of increasing atmospheric CO₂ on vegetation and the subsequent effects on ecosystems.

**DOE/ER-
0239**

Atmospheric Carbon Dioxide and the Global Carbon Cycle
(December 1985)

J. R. Trabalka (ed.), Oak Ridge National Laboratory

This volume focuses on the global cycle of carbon, the dynamic balance among global atmospheric CO₂ sources and sinks, which determines the rate of increase in the atmospheric CO₂ concentration.

**DOE/ER-
0316**

Master Index for the Carbon Dioxide Research State-of-the-Art Report Series
(March 1987)

M. P. Farrell (ed.), Oak Ridge National Laboratory

This volume is a comprehensive citation and subject index for CDRD's four State-of-the-Art reports and the two companion volumes. This comprehensive subject index has been formatted in a matrix arrangement to graphically show the distribution of subject treatment in the six reports. A glossary of terms, tables, conversion factors and other aids are also included in this volume.

**DOE/ER-
60085-H1**

Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land
(October 1986)

S. G. Warren, University of Washington

C. J. Hahn and J. London, University of Colorado

R. M. Chervin and R. L. Jenne, National Center for Atmospheric Research

Clouds exert large influences on the earth's climate by virtue of their radiative properties both in the solar and thermal-infrared spectral regions and because of their role in the hydrological cycle. These effects depend on cloud thickness, height, and water content, and therefore, it is useful to distinguish clouds by type. Currently, the surface identification of clouds by type is more accurate than identification from satellites.

This is the third in a series of atlases resulting from a study of global cloud climatology from ground-based observations. This atlas describes, for the land areas of the earth, the average total cloud cover; the amounts of each cloud type and geographical, diurnal, seasonal, and interannual variations in these quantities; and the average base heights of the low clouds. This atlas presents a method for determining the average fractional coverage of each cloud type, taking into account the overlap of different cloud types present simultaneously in a single observation. The method is designed to derive the true average amounts rather than the amounts seen from below or above. The method separately obtains the average frequency of occurrence and the average amount-when-present and multiplies these to derive the average

amount of each cloud type. These quantities are mapped for six cloud types, and the average total cloud cover is also mapped for each of four seasons at $5^\circ \times 5^\circ$ latitude-longitude resolution (poleward of 50° latitude, the size of the box is increases in longitude to maintain approximately equal area in each box). Biurnal and interannual variations of cloud type quantities are mapped at the same spatial resolution. The numbers plotted in this atlas as well as more detailed information not included in this atlas, such as average frequencies and amounts for individual year/seasons and individual reporting hours, are available on magnetic tape from the Data Support Section at the National Center for Atmospheric Research and from CDIAC.

The first two atlases in this series described the frequency of occurrence of each cloud type and the simultaneous occurrence of different types but included no information about cloud amounts. A fourth atlas, in preparation, provides data on cloud amounts for the ocean areas of the earth.

Antarctic Surges—A Clear and Present Danger? (July 1987)

**DOE/ER-
60197-H1**

U. Radok, CIRES, University of Colorado

D. Jansen and B. McInnes, University of Melbourne

Antarctic ice streams typically move hundreds of meters in a year. The investigation here outlined for nonspecialists was carried out with the support of the U.S. Department of Energy at the University of Colorado at Boulder and at the University of Melbourne, Australia, in order to determine whether polar ice streams, like some mountain glaciers, can accelerate their motion from time to time by one or two orders of magnitude in the span of a few years, with appreciable effects on global sea level.

The necessary factual background can be derived from the fact that the mass gains and losses of the Antarctic ice sheet as a whole closely balance one another. The working hypothesis that they do so exactly was used to construct three-dimensional steady-state fields of ice velocity and temperature in broad agreement with the as yet very scant observational record for the ice sheet. Next, a numerical model (due to Budd and McInnes 1974 and Budd 1975), which links the sliding motion of the ice to the energy dissipated by the friction between the ice and the underlying rock, was used to simulate the time-dependent behavior of eight ice streams representing the full range of Antarctic conditions.

In contrast to the realistic alternation between fast advances and stagnating retreats which the model had produced for some mountain glaciers known to surge, the modeled ice streams instead went from steady to irregular continuous fast sliding when the prescribed ice deformability was reduced and/or the implied lubrication by frictional heating was increased. Substantial rapid advances did not develop, except as transient phases in two experiments.

The inability of the model in general to create surges in ice streams could be due solely to its over-simplified treatment of the complex hydraulic processes taking place below the ice.

More adequate treatments of these processes are being developed and, when expanded into new self-propelled models, could show ice stream surges to be feasible. However, it may be significant that along surging glaciers the accumulation decreases and becomes strongly negative ("ablation") in the lower reaches. By contrast, the accumulation on Antarctic ice streams increases all the way from their regions of formation to the regions of discharge into the ocean. It is then possible that

ice stream surges are prevented by the strong down-stream increase in mass flow and also by the flexible restraint exerted by terminal ice shelves.

**DOE/ER-
0406**

**Global Distribution of Total Cloud Cover and Cloud Type
Amounts Over the Ocean**

(December 1988)

S. G. Warren, University of Washington

C. J. Hahn, CIRES, University of Colorado

J. London, University of Colorado

R. M. Chervin and R. L. Jenne, National Center for Atmospheric Research

These two oversized volumes (11 × 17 in.) are the third and fourth in a series of atlases that have resulted from a study of the global cloud distribution from ground-based observations. The first two atlases (NCAR/TN-201+STR and NCAR/ TN-241+STR) described the frequency of occurrence of each cloud type and the co-occurrence of different types. They did not include any information on cloud amounts. The volumes cited here describe the average total cloud cover; the amounts of each cloud type; the clouds' geographic, diurnal, seasonal, and interannual variations; and the average base heights of the low clouds. One volume does all this for the land areas of the Earth, and the other for the ocean areas. The great preponderance of each of these two volumes is made up of maps displaying the data gathered with a resolution of 5° × 5°. About 30 pp. of each volume is taken up with a narrative description, discussion, and analysis of the data and of the means used to gather the data. Graphs of data are also presented on microfiche cards. The data plotted on the maps and other data contained in these atlases are available on magnetic tape from CDIAC as Numeric Data Package NDP-026.

**DOE/ER-
0479T**

**Building an Advanced Climate Model Program Plan for the
CHAMMP Climate Modeling Program**

(December 1990)

Atmospheric and Climate Research Division, U.S. Department of Energy

The program has two aspects that are inescapably coupled and must be conducted in an increasingly comprehensive series of coordinated projects. First, advanced climate models must be developed that dramatically increase the computational throughput of climate model simulations by combining state-of-the-science supercomputing systems with advances in numerical methods and model physics. These new generation models must be used to address three critical problems: more accurate prediction of regional climatic changes that may occur over decadal to centennial periods, determination of the limits to climate predictability imposed by the inherent variability of climate as a dynamic system, and development of realistic schedules for achieving improved predictions of climatic change.

**Computer Hardware, Advanced Mathematics, and Model Physics
(CHAMMP) Pilot Project Final Report**
(May 1992)

DOE/ER-
0541T

J. Drake, Oak Ridge National Laboratory

I. Foster, Argonne National Laboratory

P. Swarztrauber, National Center for Atmospheric Research

The collaborative relationship between researchers at NCAR, ORNL, and Argonne has continued in FY 1991 and been productive in a number of areas. From a broad definition of the issues involved in using massively parallel computers for climate modeling, the group has moved to providing solutions to some of the more difficult specific problems of the parallel computation of atmospheric dynamics. In particular, algorithms have been developed and applied for

- an efficient Legendre transform on MIMD and SIMD architectures
- parallel Fast Fourier Transforms tailored for global modeling on both MIMD and SIMD computers
- distributed semi-Lagrangian transport calculations on MIMD computers

Significant progress has also been made in understanding issues relevant to the design of massively parallel climate models. In particular, the group has completed studies of

- parallel scalability of the spectral transform and other numerical methods
- load balancing strategies and vertical parallelization for climate models

This work provides both a technical basis for developing parallel spectral climate models on MIMD and SIMD machines and a scientific basis for the design of future parallel climate models. The algorithms are now being applied in preliminary parallel implementations of the NCAR Community Climate Model (CCM2). The status of the PCCM2 is discussed in this overview. Studies of alternative numerical methods, the special transform algorithm, load distribution issues, scalability analysis, and a set of test problems designed for evaluation of numerical methods are also described in accompanying papers.

**Graduate Student Theses Supported by DOE's Environmental
Sciences Division**
(July 1995)

DOE/ER-
0649T

R. M. Cushman, Oak Ridge National Laboratory

Bobbi M. Parra, Environmental Sciences Division, U.S. DOE

This report provides complete bibliographic citations, abstracts, and keywords for 212 doctoral and master's theses supported fully or partly by the U.S. Department of Energy's Environmental Sciences Division (and its predecessors) in the following areas: Atmospheric Sciences; Marine Transport; Terrestrial Transport; Ecosystems Function and Response; Carbon, Climate, and

Vegetation; Information; Computer Hardware, Advanced Mathematics, and Model Physics (CHAMMP); Atmospheric Radiation Measurement (ARM); Oceans; National Institute for Global Environmental Change (NIGEC); Unmanned Aerial Vehicles (UAV); Integrated Assessment; Graduate Fellowships for Global Change; and Quantitative Links. Indexes are provided for major professor, university, principal investigator, program area, and keywords. This bibliography is also available in various machine-readable formats (ASCII text file, WordPerfect® files, and Papyrus™ files).

**DOE/EV-
60235-1**

Glaciers, Ice Sheets, and Sea Level: Effect of a CO₂-Induced Climatic Change
(September 1985)

Polar Research Board, National Research Council

This report summarizes the consensus of the Workshop on the Interactions between Land Ice and the Oceans (in Seattle, Washington, September 1984), mentions areas of uncertainty, and makes recommendations for research.

**DOE/NBB-
0068**

Review of Carbon Dioxide Research Staffing and Academic Support
(April 1985)

S. B. Clark, L. Howard, W. Stevenson, and J. Trice, Oak Ridge Associated Universities

The report summarizes the research staffing and academic support of the U.S. Department of Energy's Carbon Dioxide Research Division (CDRD) for 1983 and 1984. About 60% of CDRD's staff were university-affiliated and about 20% were students; however, carbon dioxide research will probably not affect the general labor market for scientists and engineers because it uses only a small part of the total labor pool. The report also discusses options for academic support by CDRD. These include: (1) modifying procurement procedures for research contracts to increase academic involvement; (2) sponsoring summer institutes on issues of interest to CDRD; and (3) supporting traveling lecture programs to inform technical and nontechnical audiences of CDRD's interests.

**Quantifying and Minimizing Uncertainty of Climate Forcing by
Anthropogenic Aerosols**
(March 1993)

**DOE/NBB-
0092T**

J. E. Penner
Lawrence Livermore National Laboratory

T. Novakov
Lawrence Berkeley Laboratory

R. J. Charlson
University of Washington

J. Ogren
NOAA Climate Monitoring and
Diagnostics Laboratory

J. M. Hales
ENVAIR

L. F. Radke
National Center for Atmospheric Research

N. Laulainen
Pacific Northwest Laboratory

S. E. Schwartz
Brookhaven National Laboratory

R. Leifer
Environmental Measurements Laboratory

L. Travis
NASA Goddard Institute for Space Studies

The clear-sky climate forcing by anthropogenic aerosols has been shown to be of sufficient magnitude to mask the effects of anthropogenic greenhouse gases over large regions. Anthropogenic aerosols are composed of a variety of aerosol types including water-soluble inorganic species (e.g., sulfate, nitrate, ammonium), organic condensed species, elemental or black carbon, and mineral dust. Estimates of the clear-sky forcing by anthropogenic sulfate aerosols and by organic biomass-burning aerosols have been published previously.

Here, we estimate the uncertainty in the forcing by these aerosol types. Estimates of the clear-sky forcing by other anthropogenic aerosol types do not even exist although the forcing by these aerosol types is thought to be smaller than that by sulfate and biomass-burning aerosols.

The cloudy-sky forcing by anthropogenic aerosols, wherein aerosol cloud condensation nuclei concentrations are increased, thereby increasing cloud droplet concentrations and cloud albedo and possibility influencing cloud persistence, may also be significant. In contrast to the situation with the clear-sky forcing, estimates of the cloudy-sky forcing by an anthropogenic aerosols are little more than guesses, and it has not been possible to quantify the uncertainty of the estimates.

This situation dictates that considerable importance be attached to quantifying forcing by the anthropogenic aerosol and to defining and minimizing uncertainties in the calculated forcings. In this article, we define a research strategy for improving the estimates of the clear-sky forcing which, if implemented, should allow these effects to be incorporated into climate models within the next several years. The strategy encompasses five major, but not necessarily coordinated, activities: surface-based observations of aerosol chemical and physical properties and the radiation field, aircraft-based observations of aerosol chemical and physical properties and the radiation field, aircraft-based observations of the same properties, process studies to refine model treatments, satellite observations of aerosol abundance and size distribution, and modeling studies to demonstrate consistency between the observations and to allow extension of the limited set of observations to the global scale. A similar strategy for defining the magnitude of the cloudy-sky forcing should also be possible, but our uncertain understanding of this forcing requires that research of a more exploratory nature be carried out prior to engaging in a large-scale experiment of the magnitude of that recommended for the clear-sky forcing.

**DOE/PE-
0094P**

Global Climate Trends and Greenhouse Gas Data: Federal Activities in Data Collection, Archiving, and Dissemination. A Report to the Congress of the United States (June 1990)

Office of Environmental Analysis, U.S. Department of Energy

This report examines the current holdings of data related to greenhouse-gas emissions and climate trends that have been collected by federal agencies; the procedures for collecting, archiving, and disseminating those data; and the coordination of those information activities. It examines what procedures are necessary for improving the availability of the data and information needed to deal with greenhouse-gas and climate-change issues. It also considers what information is needed for the scientific understanding, estimation, and projection of emissions; for the modeling of climate-system processes; for the detection and characterization of trends; and for the support of assessment and policy studies. To explain the kinds of data needed and the special requirements for processing these kinds of data, the methods for estimating greenhouse-gas emissions and for detecting climate trends are summarized.

Particular gaps in data coverage and targets of opportunity for improved data (i.e., data collected but never encoded for computer use and prepared for distribution) are identified. Additional types of data that especially need collection for special purposes have also been pointed out.

The numerous and often extensive appendixes include lists and descriptions of data sources, descriptions of data needed for specific subject areas, the theory and philosophy of data management, and a bibliography.

**DOE/EP-
0001P**

Policy Statements on Data Management for Global Change Research (July 1991)

U.S. Global Change Research Program, National Science Foundation

The overall purpose of these policy statements is to facilitate full and open access to quality data for global change research. They were prepared in consonance with the goal of the U.S. Global Change Research Program and represent the U.S. Government's position on the access to global change research data.

- The Global Change Research Program requires an early and continuing commitment to the establishment, maintenance, validation, description, accessibility, and distribution of high-quality long-term data sets.
- Preservation of all data needed for long-term global change research is required. For each and every global change data parameter, there should be at least one explicitly designated archive. Procedures and criteria for setting priorities for data acquisition, retention, and purging should be developed by participating agencies, both nationally and internationally. A clearinghouse process should be established to prevent the purging and loss of important data sets.

- Data archives must include easily accessible information about the data holdings, including quality assessments, supporting ancillary information, and guidance and aids for locating and obtaining the data.
- National and international standards should be used to the greatest extent possible for media and for processing and communication of global data sets.
- Data should be provided at the lowest possible cost to global change researchers in the interest of full and open access to data. This cost should, as a first principle, be no more than the marginal cost of filling a specific user request. Agencies should act to streamline administrative arrangements for exchanging data among researchers.
- For those programs in which selected principal investigators have initial periods of exclusive data use, data should be made openly available as soon as they become widely useful. In each case, the funding agency should explicitly define the duration of any exclusive use period.

Intercomparison of Radiation Codes in Climate Models (May 1991)

Journal of Geophysical Research, American Geophysical Union

This special section consists of a series of papers devoted to the scientific aspects of state-of-the-art methods in radiative transfer computations relevant for investigations of the Earth's atmosphere. The results discussed in the papers constitute a portion of the Intercomparison of Radiation Codes in Climate Models (ICRCCM) project, which was developed under the auspices of the World Meteorological Organization (WMO) and the International Council of Scientific Unions as supported by the Carbon Dioxide Research Division (now called Atmospheric and Climatic Research Division) of the U.S. Department of Energy (DOE). A description of the initial phase of the ICRCCM project can be found in the work by Luther et al. (*Bulletin of the American Meteorological Society* 69, 40–48, 1988). The principal objectives of ICRCCM were to develop an understanding of the various radiative transfer algorithms, to investigate the causes and the nature of the differences in the results among the various codes (including their accuracy with respect to benchmark computations), and to ascertain the sensitivity of the algorithms to a number of factors (including spectral parameters, constituent amounts, and meteorological conditions).

1. The first part of the document discusses the importance of maintaining accurate records of all transactions.

2. It then goes on to describe the various methods used to collect and analyze data.

3. The next section details the results of the study, showing a clear trend in the data.

4. Finally, the document concludes with a summary of the findings and recommendations for future research.

5. The overall conclusion is that the data strongly supports the hypothesis that was tested.

6. It is hoped that this study will provide valuable insights into the phenomenon being investigated.

7. The authors would like to thank the funding agency for their generous support of this project.

8. This work was conducted as part of a larger project on the effects of environmental factors on human behavior.

9. The data presented here is preliminary and subject to further analysis and interpretation.

10. The authors are confident that the results of this study will be of great interest to the field.

11. The study was conducted over a period of six months, during which time a large amount of data was collected.

12. The results of the study are consistent with previous research in this area.

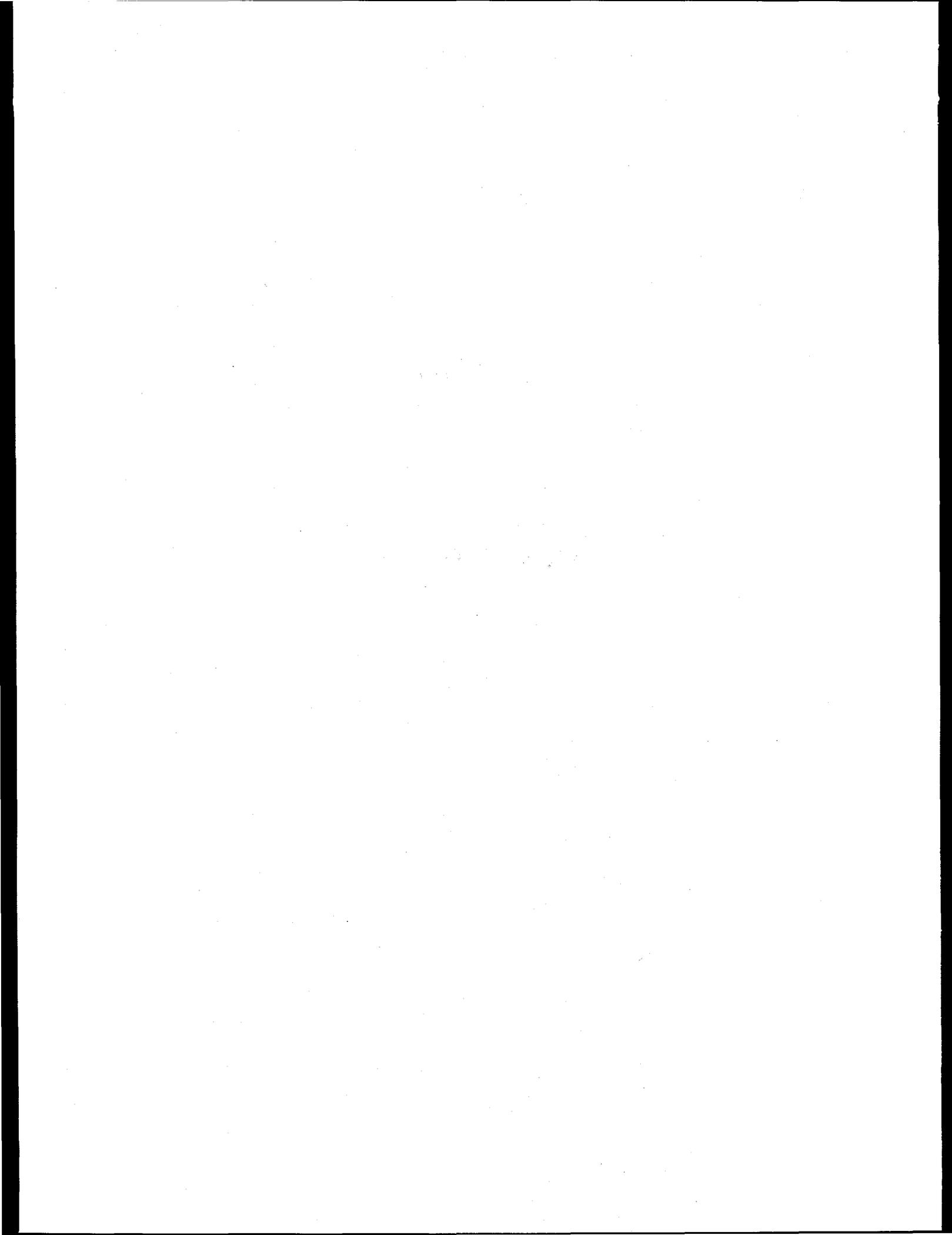
13. The authors believe that these findings have important implications for the understanding of the phenomenon.

14. The study was approved by the appropriate ethical review boards.

15. The authors would like to express their appreciation to the participants who made this study possible.

Section E

CDIAC Reports



**Graduate Student Theses Supported by Carbon Dioxide Research
Division Office of Basic Energy Sciences, U.S. Department of Energy
(September 1987)**

ORNL/
CDIAC-21

R. E. Millemann, Oak Ridge National Laboratory

The U.S. Department of Energy's Carbon Dioxide Research Division (CDRD) has a strong commitment to support graduate education. Over the years, CDRD has funded graduate thesis research, the results of which have not been summarized. The purpose of this report is to summarize information on thesis research supported by CDRD and to make it available to carbon dioxide researchers and other interested persons. The file will be updated annually. Copies of theses can be obtained upon request from CDIAC.

The information used to prepare this report was obtained through a questionnaire sent to CDRD contractors in early 1987. The cutoff date for assembling this information was August 1987, so the actual number of theses completed during 1987 may be greater than that indicated on the summary page and in the figures.

To date, 25 Ph.D. and 23 Master's theses, including 4 internship reports for the M. En. degree from Miami University (Ohio), have been written based on research supported wholly or in part by CDRD funds. Of these, 16 are in the carbon cycle area and 11 relate to climate, 17 to vegetation response, 3 to sea level, and 4 to CDIAC; a few theses are relevant to more than one program area. The number of universities involved in awarding degrees based on thesis research is 20, including one foreign university, the University of Melbourne. Of the contractors for the period 1981 through 1987, 82 responded to the questionnaire, and of these, 26 supported thesis research. Most of the contractors also served as the major professors for the students.

After the summary and figure pages, four lists appear in this report: an Author List containing the complete thesis citation, name(s) of the major professor(s), major department, contractor, and contract number; a Contractor List having the affiliation of and the thesis research supported by each contractor; a Program Area List in which the theses are grouped by subject area; and a University List in which the theses are grouped by the degree-granting institutions.

**Bibliography on Tropical Rain Forests and the Global Carbon
Cycle. Vol. 1. An Introduction to the Literature
(May 1988)**

ORNL/
CDIAC-24/V1

C. A. S. Hall, State University of New York and University of Montana

S. Brown, University of Illinois

F. M. O'Hara Jr., Consultant, Oak Ridge National Laboratory

P. B. Bogdonoff, D. Barshaw, E. Kaufman, and S. Underhill, Cornell University

This bibliography is Part I of a two-part volume; the second part will be an ecological and land-use bibliography on South Asia by J. F. Richards. World literature on tropical rain forests, tropical

deforestation, land-use change in the tropics, tropical forest conversion, and swidden agriculture as related to the global carbon cycle is covered in this bibliography. Historic papers and books are included, but comprehensive coverage was only sought for 1980 through 1987. This compendium of nearly 2000 entries forms the point of departure for a series of bibliographies on this topic. Other works in this series will be on the global carbon cycle and rain forests in specific geographic areas, whereas this volume includes references to literature about the global carbon cycle and rain forests anywhere in the world. The bibliography is ordered alphabetically by author and is indexed by subject and author.

This bibliography is the third in a series of up-to-date, specialized, and evaluated bibliographies that have been produced by the cooperative efforts of the U.S. Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) and carbon dioxide researchers.

ORNL/
CDIAC-24/V2

Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. 2. South Asia
(February 1989)

E. P. Flint and J. F. Richards, Duke University

Considerable debate has centered on the role of biotic carbon release and uptake in the global carbon cycle. Carbon release caused by deforestation may contribute significantly to increased global atmospheric CO₂. The first bibliography in this series addressed worldwide tropical rain forests and the carbon cycle, emphasizing the most recent literature. The focus of this bibliography is South Asia, primarily India, Pakistan, and Bangladesh and including some references to Nepal, Bhutan, Sri Lanka, Burma, and other nations.

This bibliography covers a range of ecological, botanical, forestry, agricultural, geological, and geographical sources for the period from 1889 to the present. References include land-use change as it affects all South Asia vegetation types, from tropical rain forests to high mountain systems to deserts. This broad scope was chosen because forests are believed to have covered most of South Asia within the past few millennia and because massive human impact is believed to be responsible for the prevalence of grassland, semidesert, and thorn forests in the regional landscape today.

Major emphases include biomass and productivity of all natural and agricultural South Asian vegetation types, forest area and volume, deforestation and environmental degradation, official land-use statistics, descriptive and quantitative studies of vegetation and animals, forest history, and local and regional case studies of land-use.

This bibliography is the fourth in a series of up-to-date, specialized, and evaluated bibliographies that have been produced by the cooperative effort of the U.S. Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) and CO₂ researchers.

Environmental Consequences of CO₂-Climate Interactions: The Need for Integrated Resource Analysis

(January 1989)

ORNL/
CDIAC-28

R. M. Cushman, J. C. Waterhouse, and M. P. Farrell, Oak Ridge National Laboratory

The increasing concentration of atmospheric carbon dioxide is expected to alter the global climate and thereby affect agriculture, forestry, fisheries, and water resources. Resources such as these interact on a regional scale, and realistic projections of the effects on these resources must take into account the important interactions and feedbacks linking them. In addition, carbon dioxide directly affects the water use and growth of vegetation; therefore, the interactive effects of carbon dioxide and climate must also be considered. These interactions and feedbacks pose a significant challenge to any attempt to model the response of resources to changing carbon dioxide and climate. In particular, model linkage and the integration of processes that operate on different spatial and temporal scales are problems that must be addressed.

A Plan for Intermodel Comparison of Atmospheric CO₂ Projections with Uncertainty Analysis

(June 1990)

ORNL/
CDIAC-32

A. W. King and M. J. Sale, Oak Ridge National Laboratory

Projecting future concentrations of atmospheric carbon dioxide (CO₂) is one of the principle objectives of the U.S. Department of Energy's Carbon Dioxide Research Program (CDRP). These projections are needed to assess the likelihood of significant global and regional change as a consequence of the continued use of fossil fuels and to determine whether alternative scenarios of future energy use can significantly alter this likelihood.

The projection of future atmospheric CO₂ concentration requires (1) estimates of the anthropogenic release of CO₂ to the atmosphere from the combustion of fossil fuels and changes in land use and (2) global carbon cycle models describing the atmospheric retention of that CO₂. However, all model projections of future CO₂ concentrations involve some degree of uncertainty. Much of this uncertainty can be attributed to (1) uncertainties in future energy and land-use emissions, (2) uncertainties about the global carbon cycle reflected in the structural and conceptual differences between models, and (3) measurement error and uncertainty in the parameters and variables within a particular model. Fortunately, methods for quantifying model uncertainty exist so that projects can be made with confidence limits that reflect the associated uncertainties.

This document is a plan for an intermodel comparison of atmospheric CO₂ projections that includes uncertainty analysis of the global carbon cycle models used to make those projections. The plan includes a procedure for the documentation, support, and archiving of global carbon cycle models within the Carbon Dioxide Information Analysis Center (CDIAC) at Oak Ridge National Laboratory (ORNL).

Uncertainty analysis is the examination of uncertainties in predictions from simulation models. The analysis identifies the dependence of model predictions on inputs, initial conditions, and parameters. Uncertainty analysis of global carbon cycle models can identify carbon cycle components and processes with the greatest sensitivities and uncertainties. This information can then be used to determine which uncertainties have the greatest influence on future atmospheric CO₂ concentrations and where further research and data collection could be most effectively applied to reduce uncertainties. An intermodel comparison of atmospheric CO₂ projections with uncertainty analysis can help define research that will improve model performance.

ORNL/
CDIAC-33

Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region

L. J. Allison, C. T. Hunsaker, R. M. Cushman, T. W. White, and J. D. Draves
Oak Ridge National Laboratory

In 1988 the U.S. Department of Energy (DOE) began an integrated research project to study the potential effect of changing climate on environmental resources. The area of study chosen was the four-state midwestern region of Iowa, Kansas, Missouri, and Nebraska. Baseline years are defined as 1984–1987 for agricultural crops and livestock and 1985 for water resources. Agriculture and water—resources that are sensitive to climate, interactive, and important to the study region and to the United States—were chosen for study. Essential to an integrated regional study is a comprehensive data base of environmental resources in the region, both to characterize the regional resources as they exist today and to serve as input for modeling the response of the resources to climate change. This atlas contains 45 maps and corresponding tabulated data showing the baseline agricultural and water resource data for the Iowa-Kansas-Missouri-Nebraska study region along with basic geographic reference data. This atlas may serve as input for modeling the response of resources to climate change and provides DOE project investigators with critical baseline agricultural and water resource data for the Iowa-Kansas-Missouri-Nebraska study region.

ORNL/
CDIAC-34/R6
(WDC-A)

Catalog of Databases and Reports (April 1995)

Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory

This document provides information about the many reports and other materials made available by the U.S. Department of Energy's Global Change Research Program (GCRP). It is divided into eight sections plus an author and a title index.

The reports in Section A provide information about the scope, activities, and direction of the GCRP. Sections B, C, D, and E contain information about research that has been sponsored by GCRP, including those produced by CDIAC. Section F describes numeric data packages (NDPs) and computer model packages (CMPs), Sec. G describes other data bases distributed by CDIAC, Sec. H. describes reports about research in the joint program of the U.S. Department of Agriculture and GCRP, and Sec. I contains reports from various workshops, symposia, and reviews.

**Documentation and Analysis of a Global CO₂ Model Developed
by Peng et al.**
(July 1990)

ORNL/
CDIAC-38

H. I. Jager, T.-H. Peng, A. W. King, and M. J. Sale, Oak Ridge National Laboratory

In 1983, Peng et al. developed a modification of the Oeschger et al. 1975 ocean model. Both the original and the modification are one-dimensional representations of the ocean, including (1) CO₂ exchange between a well mixed atmosphere and a well mixed ocean surface layer and (2) diffusive mixing into the waters lying below the mixed layer. Peng et al. also added a representation of deep-water cycling from intermediate depths to the surface polar outcrop to the ocean bottom and then back to the surface. In addition, they incorporated oceanic primary productivity into the model and benchmarked the model against the penetration of bomb-produced tritium measured by the Geochemical Ocean Sections Study (GEOSECS) program.

This report documents that modified model and describes how the model was standardized to allow comparison with other models. Before being subjected to sensitivity analysis, the standardized version of the model was supplemented with a calibration routine to define reasonable combinations of initial conditions. This routine improved the model's ability to hold an initial equilibrium state. The subsequent sensitivity analysis showed that the model was sensitive to different parameters at different points in its run time. For short runs, the initial conditions selected were of greatest importance; the significance of the initial conditions declined in longer simulations. With the pCO₂ excluded from the sensitivity analysis, ocean surface area was always second in importance. Next, the CO₂ exchange rate was most important in short runs, but the alkalinity of the oceans was in all but the shortest runs.

Glossary: Carbon Dioxide and Climate
(August 1990)

ORNL/
CDIAC-39
(WDC-A)

Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory

The impact of increased concentrations of carbon dioxide (CO₂) and other trace gases in the atmosphere is of concern in both scientific and nontechnical fields. This glossary contains definitions of selected CO₂-related terms and has been compiled to help fill the gaps in information related to climate-change terminology.

Terms in the glossary are defined with an emphasis on their relationship to CO₂ and climate. Many of the definitions are then followed by a more comprehensive discussion of the terms and their use. References to the literature from which the definitions were taken are listed at the end of the glossary.

This is the third edition of *Glossary: Carbon Dioxide and Climate*. This new edition contains more than a hundred new terms, redefinitions of many of the original terms, and an expansion of a section of tables.

In addition to terminology associated with the CO₂-climate issue, a variety of other types of nomenclature is required to fully understand crucial relations between emissions, atmospheric conditions, and changing climate. The *Glossary* also contains seven tables of International System

of Units Prefixes, common conversion factors, useful quantities found in CO₂ research, geological time scales, and abbreviations and acronyms commonly used in atmospheric research.

ORNL/
CDIAC-52

**Climate Change and Water Supply, Management and Use:
Literature Review**
(May 1992)

H. Chang, J. D. Draves, and C. T. Hunsaker, Oak Ridge National Laboratory

There is evidence that concentrations of atmospheric CO₂, tropospheric O₃, and CH₄, among other gases that contribute to the greenhouse effect, have increased in recent decades and that these changes may induce changes in global air temperatures and regional climate features in coming years. A literature review was conducted to sample the literature base on which our understanding of the water resource impacts of climate change rests. Water resource issues likely to be important include hydrologic response to climate change, the resilience of water supply systems to changing climatic and hydrologic conditions, and the effects of climate change on water quality and water uses (such as navigation and energy generation). A computer-assisted search of literature on the effects of climate change on these subjects was conducted. All studies were classified by type of paper (e.g., review, discussion, or case study), region, water resource variable studies, and source of climate scenario. The resulting bibliography containing more than 200 references was largely annotated. Case studies of potential hydrologic impacts have been more common than studies of impacts on water management or water use, but this apparent gap is closing. Case studies demonstrating methods of incorporating potential risks of climate change into water project planning and management have been performed. Considerable variability in regional coverage exists; the Great Lakes basin and California receive relatively more attention than such regions as New England and the Missouri River basin. General circulation mode-based and hypothetical climate scenarios have been the dominant sources of climate scenarios used in case studies, although a variety of other methods for developing climate scenarios have been developed.

ORNL/
CDIAC-54

**Adapting to Sea-Level Rise in the U.S. Southeast: The Influence
of Built Infrastructure and Biophysical Factors on the Inundation
of Coastal Areas**
(November 1992)

R. C. Daniels, The University of Tennessee and Oak Ridge National Laboratory

V. M. Gornitz, Goddard Institute for Space Studies

A. J. Mehta, and S.-C. Lee, University of Florida

R. M. Cushman, Oak Ridge National Laboratory

The Earth's mean surface air temperature has increased by 0.5° C over the past 100 years. This warming trend has occurred concurrently with increases in the concentration and number of greenhouse gases in the atmosphere (e.g., CO₂, N₂O, H₂O, CH₄, and CFCs). These gases may

be partially responsible for this temperature increase and may cause this trend to accelerate in the future because of the increased amount of thermal radiation that will be trapped in the troposphere by these gases. This trapping effect may result in a net increase in the earth's global mean surface air temperature of 1.5° to 4.5° C by the year 2100. An increase in the mean surface air temperature of this magnitude could cause significant increase. This increase in sea surface temperature will cause sea levels to rise—from thermal expansion of the sea and the addition of melt waters from alpine glaciers and continental ice sheets.

To allow for the cost-effective analysis of the impacts that sea-level rise may have on the U.S. Southeast, a method is needed that will allow sites potentially at risk to be identified for study. Previously, no objective method was available to identify such sites. This project addresses the problem of potential coastal damage by using a geographic data base that has information on both physical and climatological factors to identify areas of the U.S. Southeast at risk to inundation or accelerated erosion as a result of sea-level rise. The following six areas were selected for further study from the many identified as being at high risk: Galveston, Texas; Caminada Pass, Louisiana; Bradenton Beach, Florida; Daytona Beach, Florida; McClellanville, South Carolina; and Nags Head, North Carolina. These six areas are representative of three of the major stages of economic development on the East and Gulf coasts (i.e., urban/residential, undeveloped/rural, and resort/ recreational), consequently any conclusion drawn from these case studies may be generalized to other high risk regions with similar geologic and economic histories.

For each study area the amount of land, by land-use type, in danger from inundation was calculated for three sea-level-rise scenarios. The calculated values were based on elevation alone. These studies were then extended by considering the effects that built infrastructure (e.g., seawalls) and biophysical factors (e.g., erosion/accretion rates) would have on the actual amount of land that would be inundated if the sea were allowed to advance unchecked. By considering these factors, a best-guess estimation of the amount of land that may be lost to the sea was derived for each study area and each scenario. These estimated values consider both natural (e.g., elevation and erosion/accretion) and anthropogenic (e.g., built infrastructure) effects when predicting the future location of the coastline in the years 2050 and 2100 for each study area, for each scenario.

Selected Translated Abstracts of Russian-Language Climate-Change Publications. I. Surface Energy Budget (September 1992)

ORNL/
CDIAC-57

C. B. Ravina, All-Russian Research Institute of Hydrometeorological Information

M. D. Burtis, Oak Ridge National Laboratory

This report presents abstracts (translated into English) of important Russian-language literature concerning the surface energy budget as it relates to climate change. In addition to the bibliographic citations and abstracts translated into English, this report presents the original citations and abstracts in Russian. Author and title indexes are included to assist the reader in locating abstracts of particular interest.

ORNL/
CDIAC-62

CDIAC Catalog—Numeric Data Packages and Computer Model Packages
(May 1993)

Thomas A. Boden, Oak Ridge National Laboratory

Frederick M. O'Hara, Jr., Consultant, Oak Ridge National Laboratory

Frederick W. Stoss, University of Tennessee and Oak Ridge National Laboratory

The Carbon Dioxide Information Analysis Center acquires, quality-assures, and distributes to the scientific community numeric data packages (NDPs) and computer model packages (CMPs) dealing with topics related to atmospheric trace-gas concentrations and global climate change. These packages include data on historic and present atmospheric CO₂ and CH₄ concentrations, historic and present oceanic CO₂ concentrations, historic weather and climate around the world, sea-level rise, storm occurrences, volcanic dust in the atmosphere, sources of atmospheric CO₂, the response of plants to elevated CO₂ levels, sunspot occurrences, and many other indicators of, contributors to, or components of climate change. This catalog describes the packages presently offered by CDIAC, reviews the processes used by CDIAC to assure the quality of the data contained in these packages, notes the medium on which each package is available, describes the documentation that accompanies each package, and provides ordering information. Numeric data are available in the printed NDPs and CMPs, in CD-ROM format, and from an anonymous FTP area via Internet. All CDIAC information products are available at no cost.

ORNL/
CDIAC-64

Selected Translated Abstracts of Russian-Language Climate-Change Publications. II. Clouds
(January 1994)

C. B. Ravina, All-Russian Research Institute of Hydrometeorological Information

M. D. Burtis, Oak Ridge National Laboratory

This report presents abstracts (translated into English) of important Russian-language literature concerning clouds as they relate to climate change. In addition to the bibliographic citations and abstracts translated into English, this report presents the original citations and abstracts in Russian. Author and title indexes are included to assist the reader in locating abstracts of particular interest.

Trends '93: A Compendium of Data on Global Change
(August 1994)ORNL/
CDIAC-65

T. A. Boden and D. P. Kaiser, Oak Ridge National Laboratory

R. J. Sepanski and F. W. Stoss, University of Tennessee, Energy, Environment, and Resources Center

This document provides synopses of frequently used global-change data. This third issue of the *Trends* series presents historical and modern records of atmospheric concentrations of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), two chlorofluorocarbons (CFC-11 and CFC-12), a hydrochlorofluorocarbon (HCFC-22), and two halons (H-1301 and H-1211) from an expanded number of globally distributed sites. Virtually all of the modern records extend into the 1990s, some into 1994. Additional trace gas data presented in *Trends '93* include historical atmospheric CO₂, CH₄, and N₂O records derived from ice cores. *Trends '93* also includes revised and updated estimates through 1991 for global, regional, and national CO₂ emissions produced from the burning of fossil fuels, gas flaring, and the production of cement. Updated global emissions estimates through 1992 are presented for CFC-11 and CFC-12. *Trends '93* also updates and expands the presentation of long-term temperature records, whose spatial coverage ranges from an individual Antarctic ice core site to the entire globe and from the Earth's surface to the lower stratosphere. New subject matter appearing in *Trends '93* includes a chapter for long-term regional precipitation records, several time-series records for atmospheric aerosols, and isotopic ¹⁴C measurements for atmospheric CO₂ from several globally distributed sites.

Data records are presented in multipage formats, each dealing with a specific site, region, or emissions species. The data records include tables; graphs; discussions of methods for collecting, measuring, and reporting the data; trends in the data; and references to literature providing further information.

Instructions for citing contributions by the principal investigator(s) are provided for each data summary.

Report of the International Workshop on Quality Control of Monthly Climate Data
(October 1993)ORNL/
CDIAC-69

National Climatic Data Center

Monthly climate data must rely on quality control techniques that are predominantly statistical. While the actual quality control may use numerical formulae or visual inspections of graphs, at the heart of most techniques are some basic statistical relationships. These relationships primarily fall into three categories: (1) relationships of data elements to themselves (e.g., outliers from long-term means), (2) relationships to nearby data (e.g., neighbor checks), and (3) relationships to some other data parameter (e.g., sea level pressure to station pressure). The purpose of this workshop was to discuss these data relationships and other quality control techniques, to relate experiences

in applying quality control to data, and to organize cooperation in the production of quality control software.

ORNL/
CDIAC-70

Direct Effects of Atmospheric CO₂ Enrichment on Plants and Ecosystems: An Updated Bibliographic Data Base
(June 1994)

Boyd R. Strain and Jennifer D. Cure, Duke University

This publication provides bibliographic citations and abstracts on recent literature concerning the direct effects of elevated atmospheric concentrations of carbon dioxide (CO₂) on plants and ecosystems. This report is an update to *Direct Effects of Atmospheric CO₂ Enrichment on Plants and Ecosystems: A Bibliography with Abstracts* (ORNL/CDIC-13), also by Boyd R. Strain and Jennifer D. Cure, which was published in 1986.

The updated bibliography provides complete bibliographic citations, abstracts, keywords, and common and scientific plant names for approximately 800 references, published between 1980 and 1994 (half the cited references were published in 1990 or later). Many of the papers included in this volume, particularly papers from Europe, reflect a renewed interest in growth analysis as a way of studying allocation of mass and energy to the various organ systems. A large proportion of the recent research has focused at a level of organization beyond the individual organism.

ORNL/
CDIAC-74

Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water
(Version 2—September 1994)

A. G. Dickson, Scripps Institution of Oceanography

C. Goyet, Woods Hole Oceanographic Institution

The collection of extensive, reliable, oceanic carbon data is a key component of the U.S. Joint Global Ocean Flux Study (JGOFS). A portion of the JGOFS oceanic carbon dioxide measurements will be made during the World Ocean Circulation Experiment (WOCE) Hydrographic Program with funding from the U.S. Department of Energy Special Research Grant Program 89-7A: Global survey of carbon dioxide in the oceans. A science team has been formed from the investigators supported by DOE to plan and coordinate the various activities needed to produce high quality oceanic carbon dioxide measurements under this program.

This handbook was prepared at the request of, and with the active participation of, that science team. The procedures detailed in this handbook have been agreed on by the members of the science team and describe well-tested methods. The methods, together with an appropriate quality control plan, are intended to provide standard operating procedures (SOPs) for measurements made as part of this survey. These SOPs are not the only techniques in use for measuring the parameters of the oceanic carbon system; however, they do represent the current state-of-the-art methodology for shipboard measurements.

Global Change Acronyms & Abbreviations

(May 1995)

**ORNL/
CDIAC-83**

C. T. Woodard, Oak Ridge National Laboratory

F. W. Stoss, University of Tennessee and Oak Ridge National Laboratory

This list of acronyms and abbreviations was compiled to provide the user with a ready reference for deciphering the linguistic initialisms and abridgements used in documentation about the study of global change. The terms included in the first edition were selected from a wide variety of sources: technical reports, policy documents, global change program announcements, newsletters, and other periodicals. The disciplinary interests covered by this document include agriculture, atmospheric science, ecology, environmental science, oceanography, policy science, and other fields. In addition to its availability in hard copy, the list of acronyms and abbreviations is available on DOS-formatted diskettes and through CDIAC's anonymous File Transfer Protocol (FTP) area on the Internet.

**Selected Translated Abstracts of Russian-Language Climate-
Change Publications. III. Aerosols**

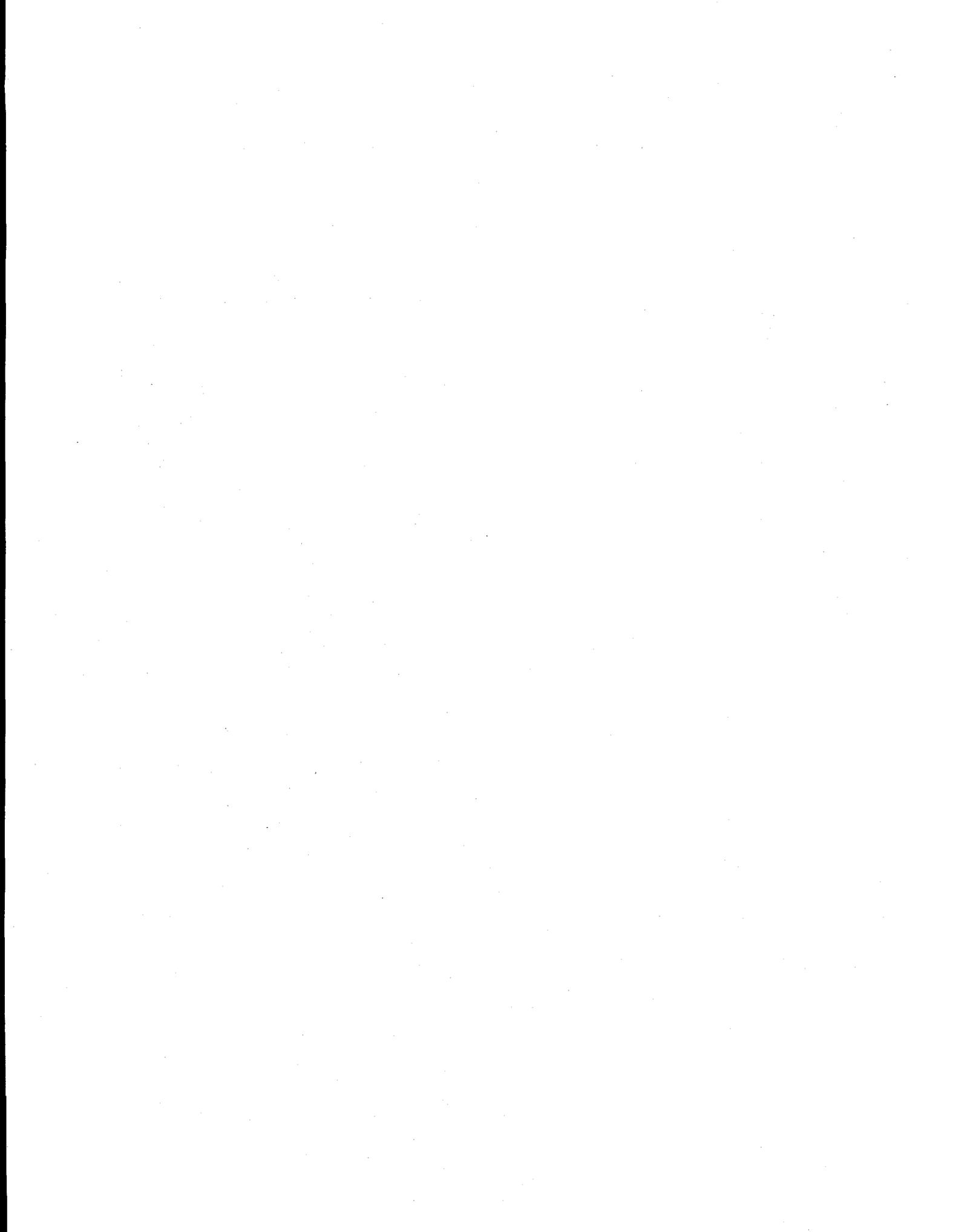
(October 1995)

**ORNL/
CDIAC-88**

V. N. Razuvaev and S. G. Sivachok

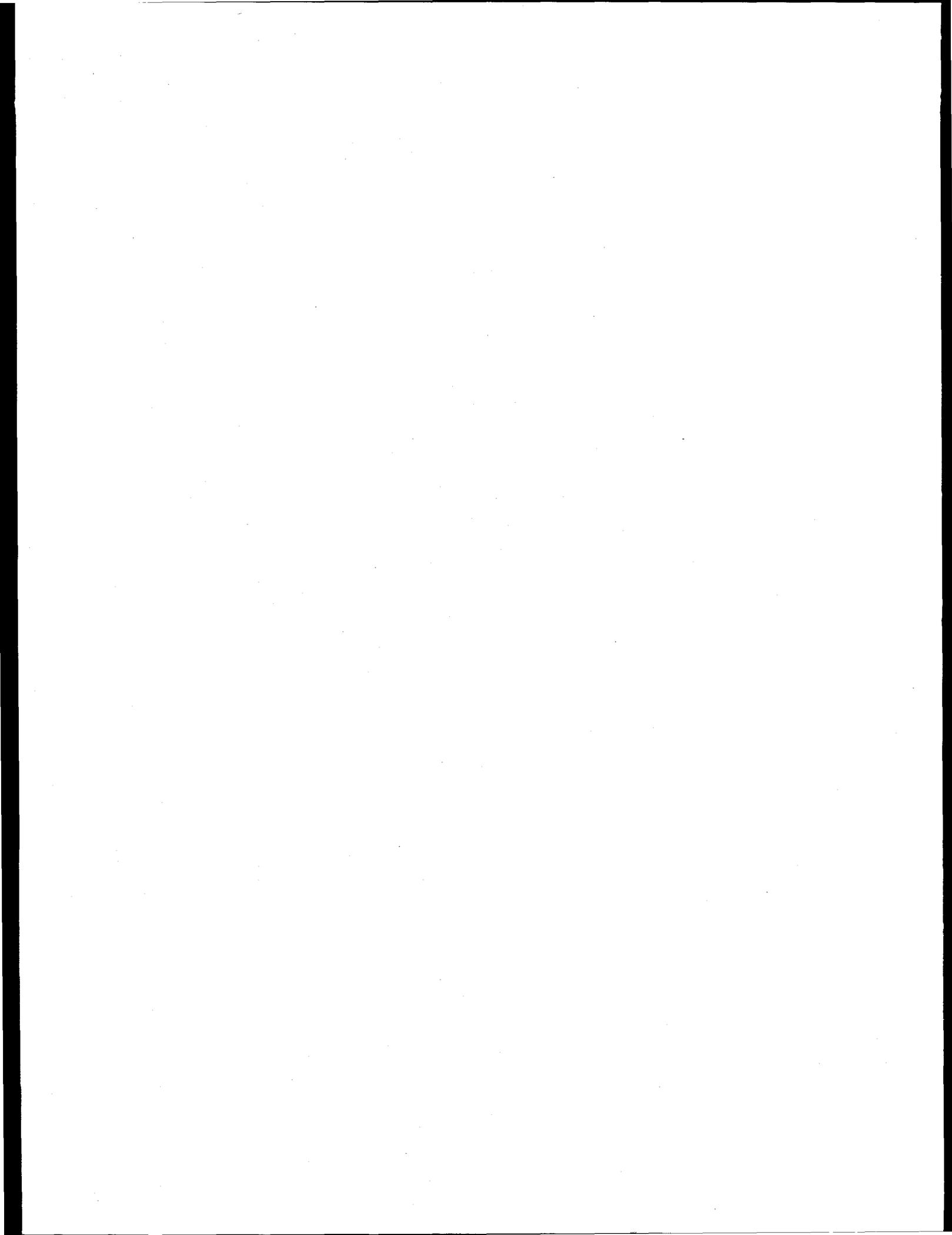
All-Russian Research Institute of Hydrometeorological Information

This report presents abstracts (translated into English) of important Russian-language literature concerning aerosols as they relate to climate change. In addition to the bibliographic citations and abstracts translated into English, this report presents the original citations and abstracts in Russian. Author and title indexes are included to assist the reader in locating abstracts of particular interest.



Section F

CDIAC Numeric Data and Computer Model Distribution



**Atmospheric CO₂ Concentrations—Mauna Loa Observatory,
Hawaii, 1958–1994**
(revised 1995)

NDP-001/R5
(WDC-A)

C. D. Keeling (contributor)

Since 1958, air samples have been continuously collected at Mauna Loa Observatory and analyzed by infrared spectroscopy for CO₂ concentrations. Data are averaged to give monthly and annual atmospheric CO₂ concentrations.

These data represent the longest continuous record of atmospheric CO₂ concentrations in the world. This precise data record covers a single site (Mauna Loa Observatory, Hawaii). It is a reliable indicator of the regional trend in the concentration of atmospheric CO₂ in the middle layers of the troposphere and is critical to CO₂-related research. The data are in one file taking 2.5 kB.

**Tree Ring Chronology Indexes and Reconstructions of Precipitation
in Central Iowa, USA**
(1984)

NDP-002

T. J. Blasing and D. N. Duvick (contributors)

Tree core samples (4 mm in diameter) were extracted from the trunks of white oak (*Quercus alba*) at three sites in central Iowa (Duvick Back Woods, Ledges State Park, and Pammel). At least 60 trees were sampled at each site, and at least two cores were taken from each tree. The growth rings of each core were dated by calendar year and measured; the measurements were then transformed into dimensionless ring-width indices and correlated with annual precipitation. Data were collected for the years 1680 through 1979. Each tree ring was characterized by the site, year, tree-ring-width index, number of core samples, decade year, and the annual reconstructed precipitation estimate. These data have more than 50% of their variance in common with the known annual statewide average precipitation for Iowa and serve as useful indicators of the precipitation and drought history of the region for the past 300 years. The data are in two files: tree-ring-chronology data (8 kB) and the annual reconstructed precipitation data for central Iowa (2 kB).

**Transient Tracers in the Oceans (TTO)—Hydrographic Data and
Carbon Dioxide Systems with Revised Carbon Chemistry Data**
(revised 1986)

NDP-004/R1
(WDC-A)

P. G. Brewer, T. Takahashi, and R. T. Williams (contributors)

The 1981 TTO North Atlantic experiment cruise consisted of seven legs and visited 250 hydrographic stations across the North Atlantic Ocean in 200 days. About 9000 water samples were taken for analysis of salinity, oxygen, and nutrients. More than 3000 samples were collected for tritium analysis, and more than 1000 samples for radiocarbon analysis. Samples were characterized hydrographically (e.g., sample depth, ocean depth, and water temperature) and chemically (e.g., alkalinity, salinity, silicate concentrations, and nitrate concentrations). They may be used for ocean-mixing studies, for testing models of ocean CO₂ uptake, and for determining the

exchange of carbon dioxide between the atmosphere and the ocean. The data are in two files [original TTO data (0.67 MB) and revised TTO data (0.86 MB)].

**NDP-005/R3 Atmospheric CO₂ Concentrations—The NOAA/GMCC Flask
(WDC-A) Sampling Network
(revised 1995)**

T. J. Conway and P. Tans (contributors)

The National Oceanic and Atmospheric Administration's Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) has measured CO₂ in air samples collected weekly at a global network of sites since the late 1970s and from two stations since the late 1960s. Determinations of atmospheric CO₂ mixing ratios on the air samples collected in glass flasks are accomplished by nondispersive infrared gas analysis. All CMDL flask samples are measured relative to standards traceable to the World Meteorological Organization (WMO) Central CO₂ Laboratory operated by C. D. Keeling at the Scripps Institution of Oceanography. These measurements constitute the most geographically extensive, carefully calibrated, internally consistent atmospheric CO₂ data set available and are essential for studies aimed at better understanding the global carbon cycle budget.

This data report documents monthly atmospheric CO₂ mixing ratios and CO₂ measurements obtained by analyzing individual flask air samples from the NOAA/CMDL global cooperative flask sampling network. Records from 40 land-based sites and from shipboard measurements covering 14 latitude bands in the Pacific Ocean and South China Sea are provided. The earliest NOAA/CMDL flask CO₂ records date back to 1967. Records through 1993 are provided for all operating sites. Approximately 60,000 individual flask CO₂ measurements are provided including those not considered indicative of regional, background, tropospheric conditions. Each measurement is flagged according to the degree the CO₂ determination satisfies the NOAA/CMDL data selection criteria.

**NDP-006 Production of CO₂ from Fossil Fuel Burning by Fuel Type,
(WDC-A) 1860–1982
(1984)**

R. M. Rotty and G. Marland (contributors)

Global carbon dioxide emissions for 1950 through 1982 were estimated by Marland and Rotty (1984) from fuel production data from the U.N. *Energy Statistics Yearbook* (1983, 1984). Data before 1950 came from Keeling (1973). Fuel-production data were used in these calculations because they appeared to be more reliable on a global basis than fuel-consumption data.

The data given are the year and annual global CO₂ emissions (annual global total; cumulative global total since 1860; and annual global emissions from solid fuels, liquid fuels, natural gas, gas flaring, and cement manufacturing). These data provide the only pre-1950 estimates of the amount of carbon emitted to the atmosphere from fossil-fuel burning. The CO₂ emission record since 1950 has been updated and revised several times with the most recent estimates being published by Marland et al. (1989). The data are in one file taking 7.5 kB.

**Atmospheric CO₂ Concentrations—The CSIRO (Australia)
Monitoring Program from Aircraft for 1972–1981
(1984)**

**NDP-007
(WDC-A)**

D. J. Beardsmore and G. I. Pearman (contributors)

From 1972 through 1981, air samples were collected in glass flasks from aircraft at a variety of latitudes and altitudes over Australia, New Zealand, and Antarctica. The samples were analyzed for CO₂ concentrations with nondispersive infrared gas analysis. The resulting data contain the sampling dates, type of aircraft, flight number, flask identification number, sampling time, geographic sector, distance in kilometers from the listed distance measuring equipment (DME) station, station number of the radio navigation distance measuring equipment, altitude of the aircraft above mean sea level, sample analysis date, flask pressure, tertiary standards used for the analysis, analyzer used, and CO₂ concentration. These data represent the first published record of CO₂ concentrations in the Southern Hemisphere expressed in the WMO 1981 CO₂ Calibration Scale and provide a precise record of atmospheric CO₂ concentrations in the troposphere and lower stratosphere over Australia and New Zealand. The data are in one file taking 263 kB.

**Annual and Seasonal Global Temperature Anomalies in the
Troposphere and Low Stratosphere, 1958–1992
(revised 1992)**

NDP-008/R3

J. K. Angell and J. Korshover (contributors)

For 1958 through 1992, the annual and seasonal temperature anomalies relative to a 1958–1977 mean (expressed in degrees Celsius) were calculated for the surface, troposphere (850–300 mb), tropopause (300–100 mb), and low stratosphere (100–50 mb and 100–30 mb) layers on regional, hemispheric, and global bases. Most of the values are column-mean temperatures obtained from the differences in height between constant-pressure surfaces at individual radiosonde stations. The pressure-height data before 1980 were obtained from published values in *Monthly Climatic Data for the World*. These temperature anomalies may be used to analyze long-term temperature trends for a layer of the atmosphere (i.e., surface, troposphere, tropopause, and low stratosphere), a region (i.e., polar, temperate, subtropical, and equatorial), a hemisphere, or the globe. The data are in one file taking 64.5 kB.

**Growth and Chemical Responses to CO₂ Enrichment—Virginia Pine
(*Pinus Virginiana* Mill.)
(1985)**

NDP-009

**R. J. Luxmoore, R. J. Norby, E. G. O'Neill, D. G. Weller, J. M. Ells, and
H. H. Rogers (contributors)**

From June 28 to October 29 in 1982, Virginia pine seedlings were exposed to elevated CO₂ levels in open-top growth chambers at one of four concentrations (75, 150, 300, and 600 ppm above ambient).

Plant dry weight; height; stem diameter; and chemical contents of leaf, stem, and root tissues were measured before and after exposure. Soil variables were also characterized.

These data illustrate the short-term physical and chemical response of Virginia pine seedlings to elevated levels of CO₂. The data are in seven files: initial dry weights before exposure (844 kB), dry weights after exposure (4 kB), major nutrient concentrations after final harvest (12 kB), minor nutrient concentrations after final harvest (17 kB), soil nutrient concentrations after final harvest (4 kB), soil leachate elements after final harvest (5 kB), and soil leachate solutes after final harvest (4 kB).

NDP-011 Global Paleoclimatic Data for 6000 Yr B.P.
(1985)

T. Webb, III (contributor)

To determine regional and global climatic variations during the past 6000 years, pollen, lake level, and marine plankton data from 797 stations were compiled to form a global data set. Radiocarbon dating and dated tephra were used to determine the ages of the specimens. The data available for the pollen data are site number, site name, latitude, longitude, elevation, and percentages of various taxa. For lake-level data, the data are site number, site name, latitude, longitude, and lake-level status. And for marine plankton, the data are site number, site name, latitude, longitude, water depth, date, dating control code, depth of sample, interpolated age of sample, estimated winter and summer sea-surface temperatures, and percentages of various taxa. The data are in 55 files: 5 files for each of 9 geographic regions and 10 supplemental files. The files for each region include (1) a FORMAT file describing the format and contents of the data for that region, (2) an INDEX file containing descriptive information about each site and its data, (3) a DATA file containing the data and available climatic estimates, (4) a PUBINDEX file indexing the bibliographic references associated with each site, and (5) a REFERENCE file containing the bibliographic references. The files range in size from 2 to 66 kB.

NDP-013 Volcanic Loading: The Dust Veil Index
(1985)

H. H. Lamb (contributor)

Lamb's Dust Veil Index (DVI) is a numerical index that quantifies the impact of a particular volcanic eruption's release of dust and aerosols over the years following the event, especially the impact on the Earth's energy balance. DVIs have been calculated for eruptions occurring from 1500 through 1983. The methods used to calculate the DVI have been intercalibrated to give a DVI of 1000 for the eruption of Krakatoa in 1883. The DVI for any volcanic eruption is based on a review of the observational, empirical, and theoretical studies of the possible impact on climate of volcanic dust veils. The DVI allows one to compare volcanic eruptions by a single numerical index. The data base includes the name of the erupting volcano, year of eruption, volcano latitude and longitude, maximum extent of the dust veil, veil duration, DVI for the entire globe, DVI for the Northern Hemisphere, and DVI for the Southern Hemisphere. The data are in one file (22.6 kB).

Solar Records: The Wolf Sunspot Index and Umbral/Penumbral Ratio NDP-014
(1985)**D. V. Hoyt (contributor)**

These data from observations of sunspot activity cover the period 1875 through 1981; reconstructions are possible back to 1832. Available sunspot models and the theory of mixing length indicate that the observed changes in the umbral/penumbral (U/P) ratio may be equivalent to changes in the solar constant. The U/P ratio is calculated from measurements of solar activity and has been shown to be in good agreement with the Northern Hemisphere temperature record. The data consist of year, number of sunspot groups, Wolf sunspot number, umbra area, whole area, penumbral area, and umbral/penumbral ratio. The data are in one file (3.3 kB).

Major World Ecosystem Complexes Ranked by Carbon in Live Vegetation: A Database NDP-017
(1985)**J. S. Olson, J. A. Watts, and L. J. Allison (contributors)**

In 1980, this data base and the corresponding map were completed after more than 20 years of field investigations, consultations, and analyses of published literature. They characterize the use and vegetative cover of the Earth's land surface with a $0.5^\circ \times 0.5^\circ$ grid. The data include latitude, longitude, and vegetation code. This world-ecosystem- complex data set and the accompanying map provide a current reference base for interpreting the role of vegetation in the global cycling of CO_2 and other gases and a basis for improved estimates of vegetation and soil carbon, of natural exchanges of CO_2 , and of net historic shifts of carbon between the biosphere and the atmosphere. The data are in one file of 109 kB.

Worldwide Organic Soil Carbon and Nitrogen Data NDP-018
(1986)**P. J. Zinke, A. G. Stangenberger, W. M. Post, W. R. Emanuel, and J. S. Olson (contributors)**

This data base was begun with the collection and analysis of soil samples from California. Additional data came from soil surveys of Italy, Greece, Iran, Thailand, Vietnam, various tropical Amazonian areas, and U.S. forests and from the soil-survey literature. The analyzed samples were collected at uniform soil-depth increments and included bulk-density determinations. The data on each sample are soil profile number; soil profile carbon content; soil profile nitrogen content; sampling site latitude and longitude; site elevation; profile literature reference source; and soil profile codes for Holdridge life zone, Olson ecosystem type, and parent material. These data may be used to estimate the size of the soil organic carbon and nitrogen pools at equilibrium with natural soil-forming factors. The data are in one file of 323 kB.

NDP-019/R3 United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data
(revised 1995)

D. R. Easterling, T. R. Karl, E. H. Mason, P. Y. Hughes, and D. P. Bowman (contributors)

Extending through 1994, this data base contains monthly total precipitation and temperature data from 1219 stations in the contiguous U.S. To be included in the Historical Climatology Network (HCN), a station had to be currently active (1994), have at least 80 years of monthly temperature and precipitation data, and have experienced few station changes. These data were derived from a variety of sources including the National Climatic Data Center archives, state climatologists, and published literature. The data base contains several hundred variables, including state number; station number; monthly temperatures (minimum, maximum, and mean); total monthly precipitation; and time of observation. This is probably the best monthly temperature and precipitation data set available for the contiguous U.S. because station moves, instrument changes, urbanization effects, and time-of-observation differences have been considered and, where necessary, the data have been corrected. The data are in 13 files [one station inventory file, one station history file, six temperature files, one precipitation file, one time-of-observation correction file, and two quality-assessment files]. The file sizes range from 5 kB to approximately 50 MB and are available on 9-track magnetic tape only.

NDP-020/R1 An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990
(revised 1991)

P. D. Jones, S. C. B. Raper, B. S. G. Cherry, C. M. Goodess, T. M. L. Wigley, B. Santer, P. M. Kelly, R. S. Bradley, and H. F. Diaz (contributors)

This NDP presents land-based monthly surface-air-temperature anomalies (departures from a 1951–1970 reference period mean) on a 5° latitude by 10° longitude global grid. Monthly surface-air-temperature anomalies (departures from a 1957–1975 reference period mean) for the Antarctic (grid points from 65°S to 85°S) are presented in a similar way as a separate data set. The data were derived primarily from the *World Weather Records* and from the archives of the United Kingdom Meteorological Office. This long-term record of temperature anomalies may be used in studies addressing possible greenhouse-gas-induced climate changes. To date, the data have been employed in producing regional, hemispheric, and global time series for determining whether recent (i.e., post-1900) warming trends have taken place.

The present updated version of this data set is identical to the earlier version for all records from 1851–1978 except for the addition of the Antarctic surface-air-temperature anomalies beginning in 1957. Beginning with the 1979 data, this package differs from the earlier version in several ways. Erroneous data for some sites have been corrected after a review of the actual station temperature data, and inconsistencies in the representation of missing values have been removed. For some grid locations, data have been added from stations that had not contributed to the original set. Data from satellites have also been used to correct station records where large discrepancies were evident. The present package also extends the record by adding monthly surface-air-temperature anomalies for the Northern (grid points from 85°N to 0°) and Southern (grid points from 5°S to 60°S) Hemispheres for 1985–1990. In addition, this updated package presents the monthly-mean-temperature records for the individual stations that were

used to produce the set of gridded anomalies. The periods of record vary by station. Northern Hemisphere data have been corrected for inhomogeneities, while Southern Hemisphere data are presented in uncorrected form.

The NDP consists of a written report and a 9-track magnetic tape (data are also available on CD-ROM or via FTP) containing 14 files, including five ASCII data files, eight FORTRAN and SAS retrieval routines, and a descriptive file. The data files range in size from 2 kB to 20 MB. Because of the size of the data files, it is not feasible to distribute these data on floppy diskettes, even as compressed files.

Historical Sunshine and Cloud Data in the United States (revised 1991)

NDP-021/R1

P. M. Steurer and T. R. Karl (contributors)

This data base presents monthly sunshine data from 240 U.S. stations (including Puerto Rico and nine Pacific Islands) and monthly cloud amount data from 197 U.S. stations. The longest periods of record are 1891 through 1987 for the sunshine data and 1871 through 1987 for the cloud data. The sunshine data were derived from measurements taken by a variety of sunshine-recording instruments. The cloud data were derived from land-based estimates of fractional cloud amount, which were made with observation practices that have varied during the period of record. Station number, station name, latitude, and longitude are given for all stations in each network. The sunshine data include monthly and annual total hours of recorded sunshine, monthly and annual maximum possible hours of sunshine, monthly and annual percentages of possible sunshine (hours recorded/hours possible), and dates of use for specific types of sunshine recorders at each station. The cloud data contain monthly and annual cloud amount (in percent of sky cover). The sunshine data are in four files: one station inventory (34.1 kB), one monthly and annual hours of measured sunshine (1.6 MB), one monthly and annual maximum possible hours of sunshine (21.5 kB), and one monthly and annual percentage of possible sunshine (2.1 MB). The cloud data are in two files: one station inventory (20.4 kB) and one monthly and annual cloud amount (2.4 MB). The data are available on 9-track magnetic tape only.

Global and Hemispheric Annual Temperature Variations Between 1861 and 1991 (revised 1994)

NDP-022/R2

P. D. Jones, T. M. L. Wigley, and P. B. Wright (contributors)

This data set contains estimates of global and hemispheric annual temperature variations, relative to a 1950 through 1979 reference period, for 1861 through 1991. The estimates are based on corrected land and ocean data. Land data were derived from meteorological data and fixed-position weather-ship data that were corrected for nonclimatic errors, such as station shifts and/or instrument changes. The marine data used were those in the Comprehensive Ocean-Atmosphere Data Set (COADS) compilation, which with updates covers to 1986. Updates to 1991 were made with hemispheric sea-surface temperature estimates produced by the U.K. Meteorological Office. Each record includes year and six annual temperature variations: one estimate each for the globe, the Northern Hemisphere, and the Southern Hemisphere and another estimate each that reflects an adjustment to account for the influence of El Niño/Southern Oscillation events. The data are in one file of 13 kB.

NDP-023/R1 Annual and Seasonal Global Variation in Total Ozone and Layer-Mean Ozone, 1958–1989
(revised 1992)

J. K. Angell, J. Korshover, and W. G. Planet (contributors)

For 1958 through 1989, this data base presents total ozone variations and layer mean ozone variations expressed as percent deviations from the 1958 to 1977 mean. The total ozone variations were derived from mean monthly ozone values published in *Ozone Data for the World* by the Atmospheric Environment Service in cooperation with the World Meteorological Organization. The layer mean ozone variations are derived from ozonesonde and Umkehr observations. The data records include year, seasonal and annual total ozone variations, and seasonal and annual layer mean ozone variations. The total ozone data are for four regions (Soviet Union, Europe, North America, and Asia); five climatic zones (north and south polar, north and south temperate, and tropical); both hemispheres; and the world. Layer mean ozone data are for four climatic zones (north and south temperate and north and south polar) and for the stratosphere, troposphere, and tropopause layers. The data are in two files [seasonal and year-average total ozone (13.4 kB) and layer mean ozone variations (24.2 kB)].

NDP-025 Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980)
(1987)

P. D. Jones, T. M. L. Wigley, and K. R. Briffa (contributors)

Real and reconstructed measurements of monthly mean pressure data have been constructed for Europe for 1780 through 1980 and North America for 1858 through 1980. The reconstructions use early pressure, temperature, and precipitation data from a variety of sources including *World Weather Records*, meteorological and national archives, circulation maps, and daily chart series. Each record contains the year, monthly mean pressure, quality code, and annual mean pressure. These reconstructed gridded monthly pressures provide a reliable historical record of mean sea-level pressures for Europe and North America. The data are in two files: pressure reconstructions for Europe (1.47 MB) and for North America (0.72 MB).

NDP-026 Climatological Data for Clouds Over the Globe from Surface Observations
(1988)

C. J. Hahn, S. G. Warren, J. London, R. L. Jenne, and R. M. Chervin (contributors)

With some data from as early as 1930, global long-term monthly and/or seasonal total cloud cover, cloud type amounts and frequencies of occurrence, low cloud base heights, harmonic analyses of annual and diurnal cycles, interannual variations and trends, and cloud type co-occurrences have been compiled and presented in two atlases (Warren et al. 1988, 1990). These data were derived from land and ship synoptic weather reports from the "SPOT" archive of the Fleet Numerical Oceanography Center (FNOC) and from Release 1 of the Comprehensive Ocean-Atmosphere Data Set (COADS) for the years 1930–1979. The data are in 12 files (one containing latitude, longitude, land-fraction, and number of land stations for

grid boxes; four containing total cloud, cloud types, harmonic analyses, and interannual variations and trends for land; four containing total cloud, cloud types, harmonic analyses, and interannual variations and trends for oceans; one containing first cloud analyses for the first year of the GARP Global Experiment (FGGE); one containing cloud-type co-occurrences for land and oceans; and one containing a FORTRAN program to read and produce maps). These files range in size from 12.5 kB to 5.67 MB and are available on 9-track magnetic tape only.

**Climatological Data for Clouds Over the Globe from
Surface Observations, 1982–1991: The Total Cloud Edition
(1994)**

NDP-026A

C. J. Hahn, S. G. Warren, and J. London (contributors)

Routine, synoptic surface weather reports from ships and land stations over the entire globe, for the 10-year period December 1981 through November 1991, were processed for total cloud cover and the frequencies of occurrence of clear sky, sky-obscured due to precipitation, and sky-obscured due to fog. Archived data, consisting of various annual, seasonal and monthly averages, are provided in grid boxes that are typically $2.5^{\circ} \times 2.5^{\circ}$ for land and $5^{\circ} \times 5^{\circ}$ for ocean. Day and nighttime averages are also given separately for each season. Several derived quantities, such as interannual variations and annual and diurnal harmonics, are provided as well. This data set incorporates an improved representation of nighttime cloudiness by utilizing only those nighttime observations for which the illuminance due to moonlight exceeds a specified threshold. This reduction in the night-detection bias increases the computed global average total cloud cover by about 2%. The impact on computed diurnal cycles is even greater, particularly over the oceans where it is found (in contrast to previous surface-based climatologies), that cloudiness is often greater at night than during the day.

**Edited Synoptic Cloud Reports from Ships and Land
Stations Over the Globe, 1982–1991
(1995)**

NDP-026B

C. J. Hahn, S. G. Warren, and J. London (contributors)

Synoptic surface weather reports for the entire globe for the 10-year period from December 1981 through November 1991 have been processed, edited, and rewritten to provide a data set designed for use in cloud analyses. The information in these reports relating to clouds, including the present weather information, was extracted and put through a series of quality control checks. Reports not meeting certain quality control standards were rejected, as were reports from buoys and automatic weather stations. Correctable inconsistencies within reports were edited for consistency, so that the "edited" cloud report can be used for cloud analysis without further quality checking. Cases of "sky obscured" were interpreted by reference to the present weather code as to whether they indicated fog, rain or snow and were given appropriate cloud type designations. Nimbostratus clouds, which have not previously been assigned a standard synoptic code, were also given a special designation. Changes made to an original report are indicated in the edited report so that the original report can be reconstructed if desired. While low cloud amount is normally given directly in the synoptic report, the edited cloud report also includes the amounts, either directly reported or inferred, of middle and high clouds, both the non-overlapped amounts and the "actual" amounts (which may be overlapped). Since illumination from the moon is important for the adequate detection of clouds at night, both the relative lunar illuminance and the solar altitude are

given, as well as a parameter that indicates whether our recommended illuminance criterion was satisfied.

This data set contains 124 million reports from land stations and 15 million reports from ships. Each report is 56 characters in length. The archive consists of 240 files, one file for each month of data for land and ocean separately. Due to the size of the database (~8 GB), the data are available on 8 mm tapes or via Internet only. With this data set, a user can develop a climatology for any particular cloud type or group of types, for any geographical region, and for any spatial and temporal resolution desired.

NDP-027 **GEOSECS Atlantic, Pacific, Indian, and Mediterranean Radiocarbon Data**
(1988)

H. G. Östlund and M. Stuiver (contributors)

Some Mediterranean Sea data were also collected. Samples for ^{14}C were collected at 124 stations, and approximately 18 samples were collected at each station from intervals throughout the water column. The data included in the data base are ship position (latitude and longitude), sample number, depth, potential temperature, salinity, and delta ^{14}C . The GEOSECS data sets allow a better understanding of large-scale oceanic transport and mixing and the establishment of the gross rate of deep-ocean circulation. The data are in three files (radiocarbon data for the Atlantic, Pacific, and Indian Oceans) ranging in size from 39.9 to 50.4 kB.

NDP-028 **Carbonate Chemistry of the Weddell Sea**
(1988)

C.-T. A. Chen (contributor)

In the late austral winter of 1981, carbonate data were obtained from the Weddell Sea as part of the U.S.-U.S.S.R. Weddell Polynya Expedition (WEPOLEX-81). Both surface samples and vertical-station samples were taken. The data include ship position (latitude and longitude), date, station number, sample depth, salinity, water temperature, pH, normalized surface total alkalinity, and calcium. These data represent the first comprehensive carbonate data obtained in the Weddell Sea during late winter. Because of the importance of the Weddell Sea as a source of deep water for the world's oceans, these data have improved the understanding of the oceanic circulation of excess CO_2 in the carbon cycle. The data are in two files [one for data from surface stations (15.5 kB) and one for data from vertical stations (5.9 kB)].

NDP-029 **Carbonate Chemistry of the North Pacific Ocean**
(1988)

C.-T. A. Chen, M. R. Rodman, C.-L. Wei, E. J. Olson, R. A. Feely, and J. F. Gendron (contributors)

Carbonate chemistry data from 41 stations in the North Pacific Ocean were obtained during two NOAA CO_2 Dynamics Cruises (June-July 1981 and May-June 1982) and two legs of the NORPAX Hawaii-Tahiti Shuttle Experiment (April 1979 and March-April 1980). The data for

each sample include ship position (latitude and longitude), date, station number, sample depth, salinity, water temperature, pH, normalized total alkalinity, and normalized calcium. The data from each of the three cruises are in separate files ranging in size from 7.1 kB to 10.1 kB.

Global, Regional, and National Annual CO₂ Emission Estimates from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950–1992
(revised 1995)

NDP-030/R6
(WDC-A)

G. Marland, R. J. Andres, and T. A. Boden (contributors)

For 1950 through 1992, global, regional, and national annual estimates of CO₂ emissions from fossil fuel burning, cement production, and gas flaring were calculated. These estimates, derived primarily from energy statistics published by the United Nations, were calculated using the methods of Marland and Rotty (1984). Cement production estimates from the U.S. Department of Interior's Bureau of Mines were used to estimate CO₂ emitted during cement production. Emissions from gas flaring were derived primarily from U.N. data but were supplemented with data from the U.S. Department of Energy's Energy Information Administration, Rotty (1974), and with a few national estimates provided by G. Marland. The resulting database contains CO₂ emission estimates (total emissions; emissions from solid, liquid, and gas fuels; emissions from cement production; emissions from gas flaring; and per capita emissions) and the statistics used to calculate them. The data are in nine files (three for the U.N. energy statistics; one for the Bureau of Mines cement production data; one for gas flaring estimates; one file that contains factors to convert solid fuel energy statistics into mass units; and three files containing the global, regional, and national CO₂ emissions). Collectively these files require approximately 15 MB of space with the largest single data file being approximately 8 MB.

Antarctic Surface Temperature and Pressure Data
(1989)

NDP-032

P. D. Jones and D. W. S. Limbert (contributors)

Monthly mean surface temperature and pressure data for 30 Antarctic stations (the earliest beginning in 1903 and all extending through 1988) were assembled primarily from *World Weather Records* and *Monthly Climatic Data for the World*. The data were assessed for quality and long-term homogeneity. The data presented are station name, station latitude and longitude, station elevation, first and final year of data record, year, mean monthly sea-level or station-level pressure, and mean monthly surface temperature. The data are in four files (two temperature and two pressure data files) ranging in size from 25 to 43 kB.

Atmospheric CO₂ Concentrations Derived from Flask Samples Collected at U.S.S.R.-Operated Sampling Sites
(1991)

NDP-033
(WDC-A)

A. M. Brounshtein, E. V. Faber, and A. A. Shashkov (contributors)

This NDP represents the first CDIAC data package to result from our involvement with Soviet scientists as part of Working Group (WG) VIII of the U.S.-U.S.S.R. Joint Committee on

Cooperation in the Field of Environmental Protection. The U.S.-U.S.S.R. Agreement on Protection of the Environment, established in 1972, covers a wide variety of areas, including environmental pollution, the urban environment, nature preserves, arctic and subarctic ecological systems, earthquake prediction, and institutional measures for environmental protection. WG VIII is concerned with the influence of environmental changes on climate. CDIAC's activities have been conducted under the auspices of WG VIII's "Data Exchange Management" project. (The four other WG VIII projects deal with climate change, atmospheric composition, clouds and radiation fluxes, and stratospheric ozone.) In addition to the Main Geophysical Observatory, other Soviet institutions that have been cooperating with CDIAC in the exchange of CO₂ and climate-related data include the All-Union Research Institute of Hydrometeorological Information (Obninsk) and the State Hydrological Institute (St. Petersburg).

NDP-033 presents daily atmospheric CO₂ concentrations from four U.S.S.R.-operated sampling sites [Teriberka Station (69°12' N, 35°06' E), Ocean Station Charlie (52°45' N, 35°30' W), Bering Island (55°12' N, 165°59' E), and Kotelny Island (76°06' N, 137°54' E)]. The period of record varies by station, with the earliest measurements dating back to 1983 and recent estimates from early 1991. These CO₂ concentrations are derived from air samples collected in 1.5-L stainless steel electropolished flasks and later analyzed at the Main Geophysical Observatory (St. Petersburg, U.S.S.R.) with a nondispersive infrared gas analyzer. Measurements not meeting wind direction, wind speed, interflask agreement, and climate-condition criteria were either discarded or flagged. All measurements have been corrected for drift biases introduced during flask storage.

These atmospheric CO₂ concentrations are considered indicative of regional background air conditions and are directly traceable to the World Meteorological Organization's primary CO₂ standards. These measurements support the rising trend in atmospheric CO₂ concentrations measured at other monitoring sites around the world and may be compared with similar measurements made by various monitoring programs at other northern-latitude sites.

Annual mean atmospheric CO₂ concentrations, calculated from available individual flask measurements for the four sites, have increased from 352.38 parts per million by volume (ppmv) in 1988 to 354.97 ppmv in 1990 for Teriberka Station, 343.52 ppmv in 1983 to 355.68 ppmv in 1990 for Ocean Station Charlie, 345.19 ppmv in 1986 to 354.93 ppmv in 1990 for Bering Island, and 351.96 ppmv in 1987 to 356.05 ppmv in 1990 for Kotelny Island. The atmospheric CO₂ measurements from each site show a pronounced annual seasonal oscillation caused by photosynthetic depletion during the northern growing season. The amplitudes of these seasonal oscillations are quite large (10 to 30 ppmv) and are consistent with measurement records from other northern-latitude locations.

The NDP consists of a written document and a magnetic tape containing seven files: four data files (one for each station) that provide the atmospheric CO₂ concentrations from individual flask measurements, a descriptive file, and FORTRAN and SAS computer codes to access the data files. The written document presents the atmospheric CO₂ concentrations in graphic and tabular form, describes the sampling methods, defines limitations and restrictions of the data, and describes the information on the magnetic media. The data files range in size from 0.97 to 20.01 kB. These data are also available on CD-ROM or via FTP. For those wishing to receive these data on floppy diskette, the same files are available on IBM-formatted, high- or low-density, 5.25- or 3.5-inch floppy diskettes as DOS ASCII text files.

**Atmospheric CO₂ Concentrations—The Canadian Background Air
Pollution Monitoring Network**
(1993)

NDP-034/R1
(WDC-A)

N. B. A. Trivett, V. C. Hudec, and C. S. Wong (contributors)

Flask air samples collected at roughly weekly intervals at three Canadian sites [Alert, Northwest Territories (July 1975 through July 1992); Sable Island, Nova Scotia (March 1975 through July 1992); and Cape St. James, British Columbia (May 1979 through July 1992)] were analyzed for CO₂ concentration with the measurements directly traceable to the WMO primary CO₂ standards. Each record includes the date, atmospheric CO₂ concentration, and flask classification code.

They provide an accurate record of CO₂ concentration levels in Canada during the past two decades. Because these data are directly traceable to WMO standards, this record may be compared with records from other Background Air Pollution Monitoring Network (BAPMoN) stations. The data are in three files (one for each of the monitoring stations) ranging in size from 9.4 to 20.1 kB.

**A Global Geographic Information System Data Base of Storm
Occurrences and Other Climatic Phenomena Affecting Coastal
Zones**
(1991)

NDP-035

K. R. Birdwell and R. C. Daniels (contributors)

This NDP is unique in that it represents CDIAC's first offering of ARC/INFO export data files and equivalent flat ASCII data files that may be used by raster or vector geographic information systems (GISs). The data set contains 61 variables, including information on tropical storms, hurricanes, super typhoons, extratropical cyclogenesis, polar lows, cyclonicity, influence of winds in monsoon regions, and sea-ice concentrations. Increased availability of source data has made it possible to extend the area of these data variables to regional or global coverages. All data variables except five are referenced to 1° · 1° or 5° · 5° grid cells of latitude and longitude. These data help meet the demand for new and improved climatologies of storm events and may be used in climate research studies, including the verification of general circulation models and the calculation of storm-recurrence intervals.

The NDP consists of a written report and a 9-track magnetic tape containing 34 files, including eight ARC/INFO files, flat ASCII files, and FORTRAN and SAS retrieval routines; a vector coordinate file; and a descriptive file. The data files range in size from 0.1 kB to 5.31 MB. The data are also available on CD-ROM or via FTP. For those wishing to receive these data on floppy diskettes, CDIAC will provide all except the ARC/INFO files on IBM-format, high-density 5.25- or 3.5-in. diskettes.

NDP-036 **Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises**
(1991)

H. Göte Östlund and C. Grall (contributors)

This data set presents ^{14}C activities from water samples taken at various locations and depths in the Indian and Southern oceans through the Indian Ocean (INDIGO) project. These data were collected as part of the INDIGO 1, INDIGO 2, and INDIGO 3 cruises, which took place during the years 1985, 1986, and 1987, respectively. These data have been used to estimate the penetration of anthropogenic CO_2 in the Indian and Southern oceans. The records include the station, date, ocean bottom depth, latitude and longitude, sampling depth, potential temperature, salinity, density, total CO_2 , ^{13}C , and ^{14}C activity. The data are in one file of 25 kB.

NDP-037 **Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO_2 Irrigation, and Nitrogen**
(WDC-A) (1992)

B. A. Kimball, J. R. Mauney, R. L. La Morte, G. Guinn, F. S. Nakayama, J. W. Radin, E. A. Lakatos, S. T. Michell, L. L. Parker, G. J. Peresta, P. E. Nixon III, B. Savoy, S. M. Harris, R. MacDonald, H. Pros, and J. Martinez (contributors)

This NDP presents data on the effects of continuous CO_2 enrichment of cotton during five consecutive growing seasons, 1983 to 1987, under both optimal and limiting levels of water and nitrogen. Unlike many prior CO_2 -enrichment experiments in growth chambers or greenhouses, these studies were conducted on field-planted cotton at close to natural conditions with open-top chambers. Measurements were made on a variety of crop-response variables during the growing season and upon crop harvest. The initial experiment examined the effects of varying CO_2 concentration only. During the following two seasons, the interactive effects of CO_2 concentration and water availability were studied. During the final two seasons, the interactions among CO_2 concentration, water availability, and nitrogen fertility were investigated.

The data include identification variables (such as year, institution and site codes, and treatment regimens), intermediate growth measurements (such as plant height, leaf-area index, number of flowers, and dry weight of leaves) taken at various times during the growing season, and crop-harvest results (such as lint yield, seed yield, and total aboveground dry biomass). These data will be useful in studying the possible future effects on crop production of a doubling of global atmospheric CO_2 concentrations and for validating crop-growth models designed to predict the effects of elevated CO_2 on cotton growth. The data show that, for all five growing seasons and all experimental treatments, cotton yields and plant dry weights were increased significantly by CO_2 enrichment.

The NDP includes a 48.4-kB ASCII data file, FORTRAN and SAS computer codes for accessing the data, a descriptive file, and written documentation. The documentation includes a supplemental text that describes and presents data for many other parameters, including daily weather, soil profile properties (e.g., initial soil moisture and nitrogen conditions), and irrigation and fertilizer treatments. These additional data are available from CDIAC on magnetic media upon request.

Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China
(1991)**NDP-039****S. Tao, C. Fu, Z. Zeng, and Q. Zhang (contributors)**

Two long-term instrumental data bases containing meteorological observations from the People's Republic of China (PRC) are presented in this NDP. These data sets were compiled in accordance with a joint research agreement signed by the U.S. Department of Energy and the PRC Chinese Academy of Sciences (CAS) on Aug. 19, 1987. CAS has provided records from 265 stations, partitioned into two networks of 60 and 205 stations, each providing good geographical coverage of the PRC.

The 60-station-network data contain monthly means, extremes, or totals of barometric pressure, air temperature, precipitation amount, relative humidity, sunshine duration, cloud amount, dominant wind direction and frequency, wind speed, and number of days with snow cover. Detailed station histories are presented for all 60 stations.

The 205-station-network data contain monthly mean temperatures and monthly precipitation totals; however, station histories are not currently available. Sixteen stations from these data sets (13 from the 60-station, 3 from the 205-station) have temperature and/or precipitation records beginning before 1900, whereas the remaining stations began observing in the early to mid-1900s. Records from 262 stations extend through 1988; the remaining three station records extend through the early 1980s.

The data are contained in five files [one station-inventory file for each of the networks (3.2 kB for the 60-station; 13.7 kB for the 205-station), one data file for the 60-station network (6.5 MB), one temperature data file for the 205-station network (1 MB), and one precipitation data file for the 205-station network (1 MB)].

Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations
(1993)**NDP-040****V. N. Razuvaev, E. G. Apasova, and R. A. Martuganov (contributors)**

Under an international agreement, the National Climatic Data Center (NCDC) in Asheville, N.C., is exchanging climatological information with the Research Institute of Hydrometeorological Information in Obninsk, Russia. To expedite the dissemination of these data, CDIAC, with funding provided by NCDC, is distributing one of the more useful archives acquired through this exchange: a 223-station daily data set covering from 1881 to 1989. The data set contains (1) minimum, mean, and maximum daily temperatures; (2) daily precipitation; (3) station inventory information (i.e., WMO number, name, coordinates, and elevation); (4) station history (i.e., station relocation and rain-gage replacement information); and (5) quality-assurance information (i.e., flag codes that were assigned as a result of various data checks). The data are in 18 files.

NDP-041 The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data
(1992)

R. S. Vose, R. L. Schmoyer, P. M. Steurer, T. C. Peterson, R. Heim, T. R. Karl, and J. K. Eischeid (contributors)

This NDP contains monthly temperature, precipitation, sea-level pressure, and station-pressure data for thousands of meteorological stations worldwide. The database was compiled from pre-existing national, regional, and global collections of data as part of the Global Historical Climatology Network (GHCN) project. It contains data from roughly 6000 temperature stations, 7500 precipitation stations, 1800 sea level pressure stations, and 1800 station pressure stations. Each station has at least 10 years of data, 40% have more than 50 years of data. Spatial coverage is good over most of the globe, particularly for the United States and Europe. Data gaps are evident over the Amazon rainforest, the Sahara desert, Greenland, and Antarctica.

A detailed analysis has revealed that most stations (95% for temperature and precipitation; 75% for pressure) contain high-quality data. However, gross data-processing errors (e.g., keypunch problems) and discontinuous inhomogeneities (e.g., station relocations and instrumentation changes) do characterize a small number of stations. All major data processing problems have been flagged (or corrected, when possible). Similarly, all major inhomogeneities have been flagged, although no homogeneity corrections were applied.

The NDP consists of a written report, two magnetic tapes of data, and FORTRAN and SASTM data retrieval codes. Because of the size of the data base, the NDP is not available on floppy diskette.

NDP-042 United States Historical Climatology Network Daily Temperature and Precipitation Data
(WDC-A)
(1991)

P. Y. Hughes, E. H. Mason, T. R. Karl, and W. A. Brower (contributors)

This package consists of a data base containing daily observations of maximum and minimum temperature and precipitation amounts at 138 U.S. stations. These stations are a specially chosen subset of the 1219-station United States Historical Climatology Network (HCN), which was compiled by the National Climatic Data Center (Asheville, North Carolina) and is contained in NDP-019/R1. The daily data network (referred to as the HCN/D) consists of stations considered to be the best of those in the HCN, selected to provide effective coverage of the contiguous U.S. after considering the temporal homogeneity of each station's observing times, instrument positioning, and surroundings. The data for each station extend through 1987, and most station records are complete for at least 80 years. The daily resolution of these data lends maximum flexibility for studies attempting to detect and monitor long-term climatic changes on a regional scale. The data are contained in seven files (one station-inventory file, one station-history file, and five temperature and precipitation data files). The files range in size from 10 kB to approximately 31 MB.

**A Coastal Hazards Data Base for the U.S. East Coast
(1992)**

NDP-043A

V. M. Gornitz and T. W. White (contributors)

This NDP presents data on coastal geology, geomorphology, elevation, erosion, wave heights, tide ranges, and sea levels for the U.S. east coast. These data may be used either by nongeographic database management systems or by raster or vector geographic information systems (GISs). The database integrates several data sets (originally obtained as point, line, and polygon data) for the east coast into 0.25°-latitude by 0.25°-longitude grid cells. Each coastal grid cell contains 28 data variables.

This NDP may be used to predict the response of coastal zones on the U.S. east coast to changes in local or global sea levels. Information on the geologic, geomorphic, and erosional states of the coast provides the basic data needed to predict the behavior of the coastal zone into the far future. Thus, these data may be seen as providing a baseline for the calculation of the relative vulnerability of the east coast to projected sea-level rises. This data will also be useful to research, educational, governmental, and private organizations interested in the present and future vulnerability of coastal areas to erosion and inundation.

The data are in 13 files, the largest of which is 1.42 MB; the entire data base takes up 3.29 MB, excluding the ARC/INFO™ files.

**A Coastal Hazards Data Base for the U.S. Gulf Coast
(1993)**

NDP-043B

V. M. Gornitz and T. W. White (contributors)

This document describes the contents of a digital data base that may be used to identify coastlines along the U.S. Gulf Coast at risk to sea-level rise. The data base integrates point, line, and polygon data for the U.S. Gulf Coast into 0.25° latitude by 0.25° longitude grid cells and into 1:2,000,000 digitized line segments that can be used by raster or vector geographic information systems (GIS) as well as by non-GIS data base systems. Each coastal grid cell and line segment contains data on elevations, geology, geomorphology, sea-level trends, shoreline displacement (erosion/accretion), tidal ranges, and wave heights.

To allow for the identification of coastlines at risk from sea level rise, 7 of the 22 original data variables in this data base were classified by vulnerability and used to create 7 relative risk variables. These relative risk variables range in value from 1 to 5 and may be used to calculate a coastal vulnerability index for each grid cell and/or line segment. The data for these 29 variables (i.e., the 22 original variables and 7 risk variables) have been placed into the following data formats:

1. Gridded polygon data for the 22 original data variables. Data include elevations, geology, geomorphology, sea-level trends, shoreline displacement (erosion/accretion), tidal ranges, and wave heights.
2. Gridded polygon data for the seven classified risk variables. The risk variables are classified versions of mean coastal elevation, geology, geomorphology, local subsidence trend, mean shoreline displacement, maximum tidal range, and maximum significant wave height.

3. 1:2,000,000 line segment data containing the 29 data variables (i.e., the 22 original data variables and the 7 classified risk variables).
4. Supplemental point data for the stations used in calculating the sea-level trend and tidal range data sets.
5. Supplemental line segment data containing a 1:2,000,000 digitized coastline of the U.S. Gulf Coast as defined by this numeric data package (NDP).

These data are available as an NDP from the Carbon Dioxide Information Analysis Center (CDIAC). The NDP consists of this document and machine-readable files available on 9-track magnetic tape, IBM-formatted floppy diskettes, and CD-ROM and through Internet by means of the File Transfer Protocol (FTP) from CDIAC's anonymous FTP area. This document provides sample listings of the data and detailed descriptions of the file formats; offers FORTRAN and SASTM retrieval program listings; describes the methods used in calculating each variable; discusses the sources, restrictions, and limitations of the data; provides five ARC/INFOTM export coverages and flat ASCII data files containing these data; and provides reprints of pertinent literature.

NDP-044**Surface Water and Atmospheric Carbon Dioxide and Nitrous Oxide Observations by Shipboard Automated Gas Chromatography: Results from Expeditions Between 1977 and 1990 (1992)**

R. F. Weiss, F. A. Van Woy, and P. K. Salameh (contributors)

This NDP presents the results of surface water and atmospheric carbon dioxide (CO₂) and nitrous oxide (N₂O) measurements carried out on shipboard by gas chromatography from 1977 to 1990. These data include results from 41 legs of 11 ocean surveys conducted in the Atlantic, Pacific, Indian, and Southern oceans, as well as the Mediterranean and Red seas.

The measurements were made by an automated high-precision shipboard gas chromatographic system that measures CO₂ by flame ionization after quantitative reduction to methane in a stream of hydrogen. Nitrous oxide is measured by a separate electron-capture detector. The chromatographic system measures 196 dry-gas samples a day, divided equally among the atmosphere, gas equilibrated with surface water, a low-range gas standard, and a high-range gas standard.

These data constitute one of the most extensive records available of CO₂ and, particularly, N₂O in marine air and surface seawater. The data will be valuable in modeling the ocean's role in the global cycles of carbon and nitrogen, in studies of ocean-atmosphere dynamics, and in evaluations of other methods for determining pCO₂. The records include the names of the expedition and research vessel, sample date and time, latitude and longitude, sample type (i.e., marine air or surface seawater), barometric pressure, surface water temperature, and dry-gas mole fractions of CO₂ and N₂O. The data are in 82 files totaling 7.1 MB.

Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOE sections A-12 and A-21) (1994)

NDP-045

D. W. Chipman, T. Takahashi, D. Berger, and S. C. Sutherland (contributors)

This document presents the procedures and methods used to obtain carbon dioxide (CO₂), hydrographic, and chemical data during the R/V *Meteor* Expedition 11/5 in the South Atlantic Ocean, including the Drake Passage (Section A-12); the Northern Weddell Sea; and the Eastern South Atlantic Ocean (Section A-21). This cruise was conducted as part of the World Ocean Circulation Experiment (WOCE).

The cruise started from Ushuaia, Argentina, on January 23, 1990, and ended at Capetown, South Africa on March 8, 1990. Samples were collected at 78 stations that covered the Drake Passage (56°–63°S); the Northern Weddell Sea (45°–35°W); a section along the 58°W parallel (25°W–prime meridian); and two segmented S-N sections between the Northern Weddell Sea and Capetown, South Africa. Measurements taken at WOCE sections A-12 and A-21 included pressure, temperature, salinity measured by the Conductivity, Temperature and Depth sensor (CTD); bottle salinity, oxygen; phosphate; nitrate, nitrite; silicate, total carbon concentration (TCO₂); and partial pressure of CO₂ (pCO₂) measured at 20°C. In addition, potential density at 0 decibar (dbar) and potential temperature were calculated from the measured variables.

The TCO₂ concentration in seawater samples was measured using a coulometer with an estimated precision of approximately ±1 μmol/kg. The coulometer was calibrated frequently at sea by using a high-precision gas pipette and CO₂ gas (99.998%). The pCO₂ value in seawater samples was measured at 20°C by means of a constant-volume (500 ml seawater) equilibrator and a gas chromatograph. CO₂ in equilibrated gas was first converted to methane, by using a ruthenium catalyst, and then measured by a flame-ionization detector. The precision of pCO₂ measurements has been estimated to be approximately ±0.1%.

Historic Land Use and Carbon Estimates for South and Southeast Asia: 1880–1980 (1994)

NDP-046

J. F. Richards and E. P. Flint (contributors)

This digital data base contains estimates of land use change and the carbon content of vegetation for South and Southeast Asia for the years 1880, 1920, 1950, 1970, and 1980. These data were originally collected for climate modelers so they could reduce the uncertainty associated with the magnitude and time course of historical land use change and of carbon release. For this data base, South and Southeast Asia is defined as encompassing nearly 8 × 10⁶ km² of the earth's land surface and includes the countries of India, Sri Lanka, Bangladesh, Myanmar (Burma), Thailand, Laos, Kampuchea (Cambodia), Vietnam, Malaysia, Brunei, Singapore, Indonesia, and the Philippines.

The most important change in land use over this 100-year period was the conversion of 107 × 10⁶ ha of forest/woodland to categories with lower biomass. Land thus transformed accounted for 13.5% of the total area of the study region. The estimated total carbon content of live vegetation in

South and Southeast Asia has dropped progressively, from 59×10^9 Mg in 1880 to 27×10^9 Mg in 1980.

Throughout the study period, the carbon stock in forests was greater than the carbon content in all other categories combined, although its share of the total declined progressively from 81% in 1880 to 73% in 1980.

The data base was developed in Lotus 1-2-3™ by using a sequential bookkeeping model. The source data were obtained at the local and regional level for each country from official agricultural and economic statistics (e.g., the United Nations Food and Agriculture Organization); historical geographic and demographic texts, reports, and articles; and any other available source. Because of boundary changes through time and disparities between the validity, availability, and scale of the data for each country, the data were aggregated into 94 ecological zones. The resulting data base contains land use and carbon information for 94 ecological zones and national totals for 13 countries.

The data base consists of 90 Lotus 1-2-3™ files, 3 ARC/INFO™ export files, and 5 ASCII data files. In addition to these, a descriptive file that explains the contents and format of each data file and 4 FORTRAN and SAS™ retrieval programs for use with the ASCII data files are included.

NDP-047**Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986–1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans**
(1995)

P. P. Murphy, K. C. Kelly, R. A. Feely, and R. H. Gammon (contributors)

This document presents data on carbon dioxide (CO₂) concentrations in surface water and the atmosphere collected during Pacific Marine Environmental Laboratory (PMEL) expeditions during 1986–1989. CO₂ was measured quasi-continuously on 5 PMEL expeditions (12 legs) in the Pacific and Indian Oceans. These cruises were conducted under support from the National Oceanic and Atmospheric Administration (NOAA).

CO₂ measurements in the atmosphere and in surface water were made by analyzing mixing ratios of CO₂ with an automated, temperature-controlled gas chromatograph system described by Murphy et al. (1991) and Bates et al. (1993). Instrument precision was determined by the average percent standard deviation of the standard response over a 6-h period. The precision varied between cruises but was always less than 1.2% and was more typically around 0.4%.

Air was pumped through 3/8-in. diam., plastic-coated, aluminum tubing from the jackstaff on the bow of the ship (10 m above the sea surface) to the oceanographic laboratory for analysis. Surface seawater entered the ship via a forward intake line located approximately 5 m below the water level.

Fifteen files are described in this report and distributed along with it, including one descriptive file (**readme**) that provides an overview of the cruise network and describes details on the content and format of the thirteen data files; one FORTRAN 77 retrieval code (**pmeldat.for**) that may be used to read and print any of the data files; and thirteen data files, one (**pmel8689.dat**) that contains the data from all twelve legs, and separate files (12 total) for

each leg. Each of the data files contains the same variables: cruise name; date (day, month, year); day of the year [Greenwich Mean Time (GMT)]; latitude and longitude (in decimal degrees); cumulative distance since the first sampling location on the leg; sea surface temperature ($^{\circ}\text{C}$); warming temperature [indicates the warming ($^{\circ}\text{C}$) of seawater as it transited from the intake line to the analysis site]; sea surface salinity; atmospheric pressure; reported atmospheric CO_2 concentration [$X(\text{CO}_2)_{\text{air}}$], which is the mole fraction of the dried air pumped from the bow line; reported surface seawater CO_2 concentration [$X(\text{CO}_2)_{\text{sw}}$], which is the mole fraction of the dried vapor drawn from the equilibrator headspace; the calculated fugacity values for the air [$f(\text{CO}_2)_{\text{air}}$] and seawater [$f(\text{CO}_2)_{\text{sw}}$] given in the data tables are the in situ fugacities, which have been corrected for the warming of the seawater; and data quality flags.

The data set is available free of charge, as a Numeric Data Package (NDP) from CDIAC. The NDP consists of printed documentation and machine-readable files. The data files are available on 9-track magnetic tape; IBM-formatted floppy diskettes; 8-mm tapes; and 150-mB, quarter-inch tape cartridge and from CDIAC's anonymous File Transfer Protocol (FTP) area via Internet. This document also contains an appendix, that is a full reprint of the NOAA Technical Memorandum ERL PMEL-101 authored by Murphy et al. in 1994. The appendix contains cruise information, fully describes the sampling methods and instrumentation, and defines limitations and restrictions of the data.

Six- and Three-Hourly Meteorological Observations from 223 U.S.S.R. Stations **NDP-048** (1995)

V. N. Razuvayev, E. G. Apasova, and R. A. Martuganov (contributors)

This database contains 6- and 3-hourly meteorological observations from a 223-station network of the former Soviet Union. Data from this database have been made available through cooperation between the two principal climate data centers of the United States and the former Soviet Union: the National Climatic Data Center (NCDC), in Asheville, North Carolina, and the All-Russian Research Institute of Hydrometeorological Information - World Data Centre (RIHMI-WDC) in Obninsk, Russia. Station records consist of 6- and 3-hourly observations of some 24 meteorological variables including temperature, weather type, precipitation amount, cloud amount and type, sea level pressure, relative humidity, and wind direction and speed. The 6-hourly observations extend from 1936 through 1965; the 3-hourly observations extend from 1966 through the mid-1980s (1983, 1984, 1985, or 1986, depending on the station). These data have undergone extensive quality assurance checks by RIHMI-WDC, NCDC, and the Carbon Dioxide Information Analysis Center (CDIAC). The database represents a wealth of meteorological information for a large and climatologically important portion of the earth's land area, and should prove extremely useful for a wide variety of regional climate change studies.

The NDP consists of a written document and 40 data files (~2.6 gigabytes in *uncompressed* form) that are available on 8 mm tape or via the Internet through anonymous FTP (File Transfer Protocol).

NDP-049 Carbon-13 Isotopic Abundance and Concentration of Atmospheric Methane for Background Air in the Southern and Northern Hemispheres from 1978 to 1989
(1995)

C. M. Stevens (contributor)

This data package presents atmospheric CH₄ concentration and ¹³C isotopic abundance data derived from air samples collected over the period 1978–1989 at globally distributed clean-air sites. The data set comprises 201 records, 166 from the Northern Hemisphere and 35 from the Southern Hemisphere. The air samples were collected mostly in rural or marine locations remote from large sources of CH₄ and are considered representative of tropospheric background conditions. The air samples were processed by isolation of CH₄ from air and conversion to CO₂ for isotopic analysis by isotope ratio mass spectrometry.

These data represent one of the earliest records of ¹³C isotopic measurements for atmospheric methane and have been used to refine estimates of CH₄ emissions, calculate annual growth rates of emissions from changing sources, and provide evidence for changes in the rate of atmospheric removal of CH₄. The data records consist of sample collection date; number of samples combined for analysis; sampling location; analysis date; CH₄ concentration; ¹³C isotopic abundance; and flag codes to indicate outliers, repeated analyses, and other information. The data are contained in one 21.5 kB file.

NDP-050 Continental Scale Estimates of the Biotic Carbon Flux from Land Cover Change: 1850 to 1980
(1995)

R. A. Houghton and J. L. Hackler (contributors)

This data package contains annual carbon flux estimates from land cover change for nine regions of the world (i.e., North America, Europe, the former Soviet Union, Pacific developed region, China, South and Central America, North Africa–Middle East, tropical Africa, and south and southeast Asia). Annual rates of land cover change and vegetation–soil response curves for each region and ecosystem are included in the database. The vegetation–soil response curves are used in our bookkeeping carbon model to estimate (1) the carbon flux in the atmosphere from clearing or degradation of vegetation, cultivation of soils, decay of dead vegetation, and (2) the recovery of abandoned lands. The model calculates the net flux of carbon in each region based on the land cover change rates and vegetation–soil response curves for the period 1850–1980 (a few regions have land cover records that begin in 1700 and carbon flux data ending in 1990). These data were collected and modeled in an attempt to reduce the uncertainty associated with the magnitude and time course of the flux of carbon from terrestrial vegetation to the atmosphere.

**Carbon Dioxide, Hydrographic, and Chemical Data Obtained
During the R/V *Meteor* Cruise 15/3 in the South Atlantic Ocean
(WOE Section A9, February–March 1991)
(June 1995)**

NDP-051

K. M. Johnson, D. W. R. Wallace, R. J. Wilke, and C. Goyet (contributors)

This data documentation discusses the procedures and methods used to obtain data on total carbon dioxide (TCO₂), total alkalinity (TALK), and discrete partial pressure of CO₂ (pCO₂) during the Research Vessel (R/V) *Meteor* Expedition 15/3 in the South Atlantic Ocean (Section A9). Conducted as part of the World Ocean Circulation Experiment (WOE), the cruise began in Vitoria, Brazil, on February 10, 1991, and ended in Pointe-Noire, Congo, on March 23, 1991. WOE zonal Section A9 began at ~38° W and continued along the 19° S parallel until ~8° E. Samples were collected for TCO₂ from 28 stations along the 19th parallel and at 3 diversions north and south of the 19th parallel. The latter stations were occupied to track bottom water movements. Measurements made along WOE Section A9 included pressure, temperature, salinity, and oxygen measured by conductivity, temperature and depth sensor (CTD) as well as bottle salinity, oxygen, phosphate, nitrate, nitrite, silicate, CFC-113, CCl₄, CFC-12, CFC-11, TCO₂, TALK, and pCO₂ measured at 20°C. Replicate samples from ten Niskin bottles at four stations were also collected for later shore-based reference analyses of TCO₂ and TALK by vacuum extraction and manometry in the laboratory of Dr. Charles Keeling, Scripps Institution of Oceanography (SIO).

**Total Carbon Dioxide, Hydrographic, and Nitrate Measurements
in the Southwest Pacific During Austral Autumn, 1990: Results
from NOAA/PMEL CGC-90 Cruise
(September 1995)**

NDP-052

M. F. Lamb, R. A. Feely, L. Moore, and D. K. Atwood (contributors)

This document presents the procedures and methods used to obtain total carbon dioxide (TCO₂), hydrographic, and nitrate data during the NOAA/PMEL research vessel (R/V) *Malcolm Baldrige* CGC-90 Cruise. Data were collected along two legs; sampling for Leg 1 began along 170° W from 15° S to 60° S, then angled northwest toward New Zealand across the Western Boundary Current. Leg 2 included a reoccupation of some stations between 30° S and 15° S on 170° W and measurements from 15° S to 5° N along 170° W. Along the cruise track 68 CTD stations were occupied for collection of chemical and hydrographic data. The data report summarizes the TCO₂, salinity, temperature, and nitrate measurements from 63 stations. In addition, potential density and potential temperature were calculated from the measured variables.

**Rattlesnake Mountain Observatory (46.4° N, 119.6° W)
Multispectral Optical Depth Measurements: 1979–1994
(September 1995)**

NDP-053

N. R. Larson, J. J. Michalsky, and B. A. LeBaron (contributors)

Surface measurements of solar irradiance of the atmosphere were made by a multipurpose computer-controlled scanning photometer at the Rattlesnake Mountain Observatory in eastern Washington. The observatory is located at 46.4° N, 119.6° W at an elevation of 1088 m above

mean sea level. The photometer measures the attenuation of direct solar radiation for different wavelengths with 12 filters. Five of these filters (i.e., at 428 nm, 486 nm, 535 nm, 785 nm, and 1010 nm, with respective half-power widths of 2, 2, 3, 18, and 28 nm) are suitable for monitoring variations in the total optical depth of the atmosphere.

NDP-054 **Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V *Thomas Washington* July–August, 1991**
(April 1996)

T. Takahashi, G. Goddard, S. Rubin, D. W. Chipman, S. C. Sutherland, and C. Goyet
(contributors)

This data documentation discusses the procedures and methods used to obtain data on total carbon dioxide (TCO₂), total alkalinity (TALK), and discrete partial pressure of CO₂ (pCO₂) during the Research Vessel (R/V) *Thomas Washington* TUNES Leg 2 Expedition in the central South Pacific Ocean. Conducted as part of the World Ocean Circulation Experiment (WOE), the cruise began in Papeete, Tahiti, French Polynesia, on July 16, 1991, and returned to Papeete on August 25, 1991. WOE zonal Sections P17S along 135° W and P16S along 150° W were completed during the 40-day expedition. A total of 97 hydrographic stations were occupied. Hydrographic and chemical measurements made along WOE Sections P17S and P16S included pressure, temperature, salinity, and oxygen measured by conductivity, temperature and depth sensor as well as bottle salinity, oxygen, phosphate, nitrate, nitrite, silicate, CFC-12, CFC-11, TCO₂, TALK, and pCO₂ measured at 20°C.

CMP-002 **The IEA/ORAU Long-Term Global Energy-CO₂ Model**
(1984)

J. A. Edmonds and J. M. Reilly (contributors)

This mathematical model, written in FORTRAN IV and adapted for use on an IBM® 370/3033, makes projections concerning global energy and CO₂ emissions at 25-year intervals from 1975 through 2100 based on economic, demographic, and energy interactions. The model separates the world into nine regions, each having four components: demand, supply, energy balance, and CO₂ emissions. Energy demand is a function of the population, economic activity, technological change, energy prices, and energy taxes and tariffs existing in each region. Supply is dependent upon resource constraints, behavioral assumptions, and energy prices in a region. Energy balance reconciles the global energy supply and demand for fuels. Emissions are determined by applying appropriate carbon coefficients at the points in the energy flow where carbon is released. The model offers three energy/emission scenarios through 2100 and illustrates the complex relationships between global CO₂ emissions, rising populations, and energy parameters. The model is in nine files, three containing the source code and subroutines and one input-data and one output file each for low, mid, and high cases. These files range in size from 45.6 to 422 kB and are available on 9-track magnetic tape only.

**The IEA/ORAU Long-Term Global Energy-CO₂ Model: Personal
Computer Version A84PC
(1995)**

**CMP-002/PC/R1
(WDC-A)**

J. A. Edmonds, J. M. Reilly, and D. W. Barns (contributors)

The IBM® PC version of the Edmonds-Reilly model reflects considerable refinements and improvements over the mainframe version (see CDIAC CMP-002). It has the capability to calculate both CO₂ and CH₄ emission estimates by source and region. The basic methodology and features of the PC version are the same as those for the mainframe version. Population, labor productivity, end-use energy efficiency, income effects, price effects, resource base, technological change in energy production, environmental costs of energy production, market-penetration rate of energy-supply technology, solar and biomass energy costs, synfuel costs, and the number of forecast periods may be interactively inspected and altered producing a variety of global and regional CO₂ and CH₄ emission scenarios for 1975 through 2100. The executable versions of the model and the source code are contained in 74 files ranging in size from 10 bytes to 292 kB.

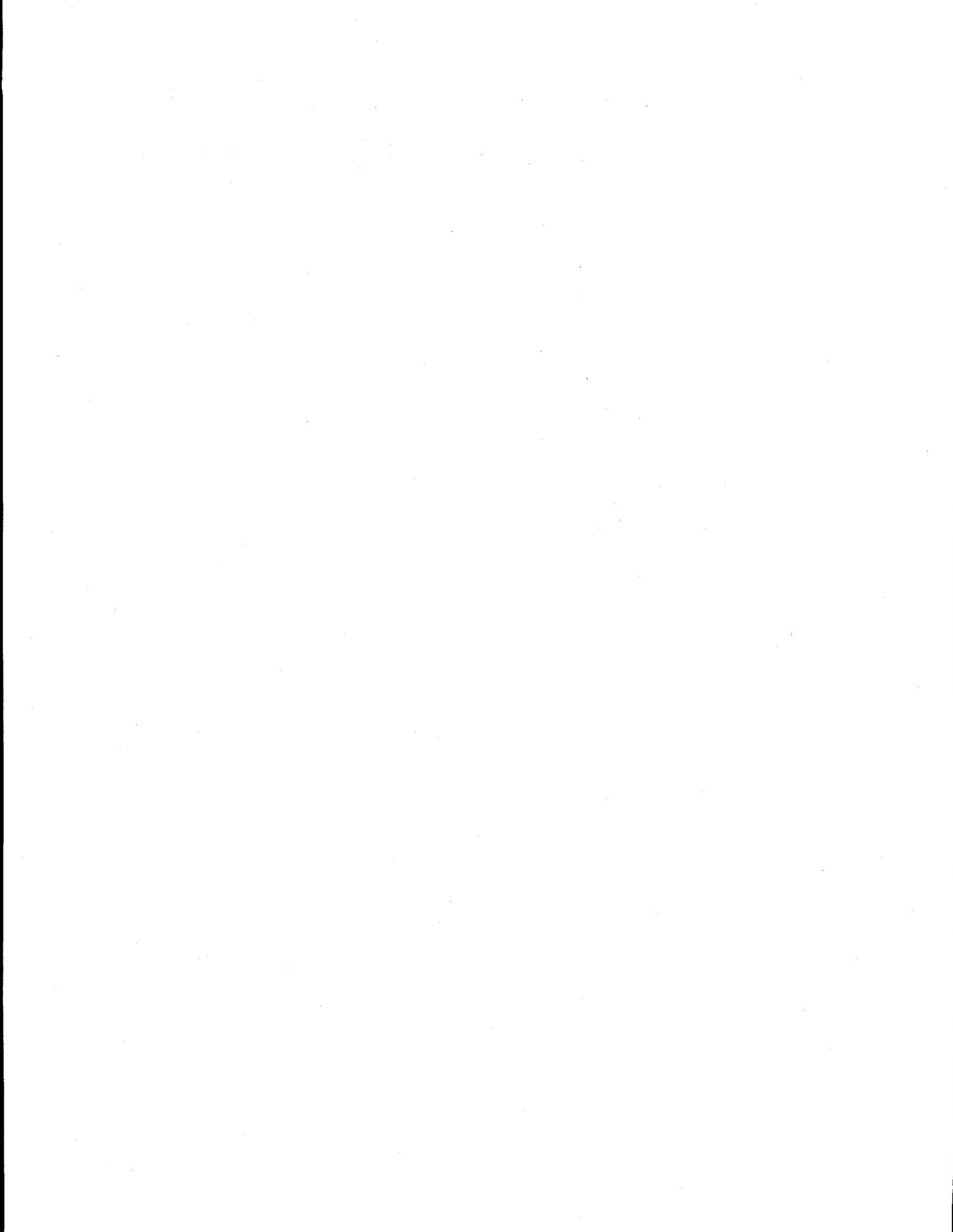
**CDIAC's Numeric Data Package Collection: Selected Data Sets
Relevant to Studies of Greenhouse Gases and Climate
(1993)**

**CD-ROM
Ver. 1.02**

T. A. Boden and T. R. Nelson (contributors)

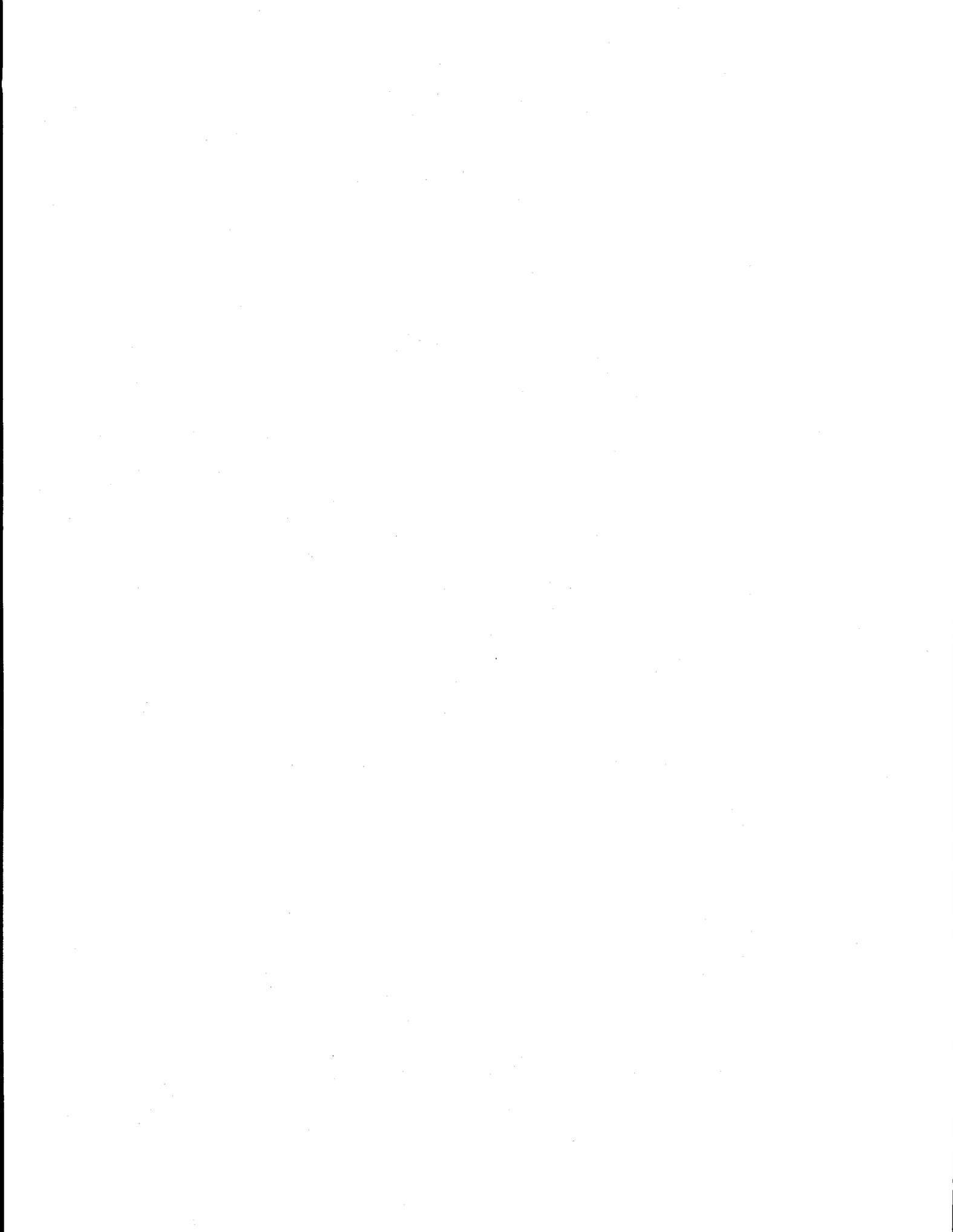
This two-volume CD-ROM provides data files, retrieval codes, and descriptive files for selected NDPs and CMPs, data from selected technical reports, and the data from *Trends '91: A Compendium of Data on Global Change*. A full listing of NDPs and CMPs is available in the *CDIAC Catalog of Numeric Data Packages and Computer Model Packages*. The CD's data bases are arranged as subdirectories, each subdirectory corresponding to an NDP number (e.g., NDP-001/R3). The first CD-ROM of this two-volume set contains all subdirectories except for NDP-041, NDP-042, and NDP-044. These subdirectories are provided on the second volume.

Within each subdirectory, the user will find a descriptive file (*.DES or README) that outlines the basis contents and formats of the other files in the subdirectory. All the data bases provided on these CD-ROMs are fully documented and are also available on 9-track magnetic tape; IBM-formatted, floppy diskettes; or through CDIAC's anonymous FTP (file transfer protocol) area via Internet. To receive the complete documentation for an NDP, please contact CDIAC.



Section G

Other Data Sets Distributed by CDIAC



The ALE/GAGE/AGAGE Network

DB1001/R1

R. Prinn, D. Cunnold, P. Fraser, R. Weiss, P. Simmonds, B. Miller, F. Alyea, and A. Crawford. (contributors)

In the ALE/GAGE/AGAGE global network program, continuous high frequency gas chromatographic measurements of two biogenic/anthropogenic gases (methane, CH₄; nitrous oxide, N₂O; and five anthropogenic gases (chlorofluorocarbons CFC₁, CF₂Cl₂, and CF₂C₁CF₂; methyl chloroform, CH₃CCl₃; carbon tetrachloride, CCl₄) are carried out at globally distributed sites. The program, which began in 1978, is conveniently divided into three parts associated with three changes in instrumentation: the Atmospheric Lifetime Experiment (ALE), which utilized Hewlett Packard HP5840 gas chromatographs; the Global Atmospheric Gases Experiment (GAGE), which utilized HP5880 gas chromatographs; and the recently initiated Advanced GAGE (AGAGE). AGAGE uses a new fully automated system from the Scripps Institution of Oceanography containing a custom-designed sample module and HP5890 and Carle Instruments gas chromatographic components.

The current station locations are Cape Grim, Tasmania (41°S, 145°E), Point Matatula, American Samoa (14°S, 171°E), Ragged Point, Barbados (13°N, 59°W), and Mace Head, Ireland (53°N, 10°W). Stations also previously existed at Cape Meares, Oregon (45°N, 124°W), and Adrigole, Ireland (52°N, 10°W). The current Mace Head station replaced the Adrigole station and a station is planned at Trinidad Head, California (41°N, 124°W) to replace Cape Meares.

Presently, data from the ALE and GAGE experiments are available. Data from AGAGE are not yet available. Individual measurements (generally made 4 times daily at each site for ALE and 12 times daily at each site for GAGE) and monthly summary averages are provided for each site.

ICRCCM Infrared (Clear-Sky) Line-by Line Radiative Fluxes

DB1002

A. Arking, B. Ridgway, T. Clough, M. Iacono, B. Fomin, A. Trotsenko, S. Freidenreich, and D. Schwarzkopf (contributors)

The intercomparison of Radiation Codes in Climate Models (ICRCCM) study was launched under the auspices of the World Meteorological Organization and with the support of the U.S. Department of Energy to document differences in results obtained with various radiation codes and radiation parameterizations in general circulation models (GCMs). ICRCCM produced benchmark, longwave, line-by-line (LBL) fluxes that may be compared against each other and against models of lower spectral resolution.

During ICRCCM, infrared fluxes and cooling rates for several standard model atmospheres with varying concentrations of water vapor, carbon dioxide, and ozone were calculated with LBL methods at resolutions of 0.01 cm⁻¹ or higher. For comparison with other models, values were summed for the IR spectrum and given at intervals of 5 or 10 cm⁻¹.

This archive contains fluxes for ICRCCM-prescribed clear-sky cases. Radiative flux and cooling-rate profiles are given for specified atmospheric profiles for temperature, water vapor, and ozone-mixing ratios. The archive contains 328 files, including spectral summaries, formatted data files, and a variety of programs (i.e., C-shell scripts, FORTRAN codes, and IDL programs) to read, reformat, and display data. Collectively, these files require approximately 59 MB of disk space.

DB1003 A Computer-Based Atlas of Global Instrumental Climate Data

R. S. Bradley, L. G. Ahern, and F. T. Keimig (contributors)

Color-shaded and contoured images of global, gridded instrumental data have been produced as a computer-based atlas. Each image simultaneously depicts anomaly maps of surface temperature, sea-level pressure, 500-mbar geopotential heights, and percentages of reference-period precipitation. Monthly, seasonal, and annual composites are available in either cylindrical equidistant or northern and southern hemisphere polar projections. Temperature maps are available from 1854 to 1991, precipitation from 1851 to 1989, sea-level pressure from 1899 to 1991, and 500-mbar heights from 1946 to 1991. The source of data for the temperature images is Jones et al.'s global gridded temperature anomalies. The precipitation images were derived from Eischeid et al.'s global gridded precipitation percentages. Grids from the Data Support Section, National Center for Atmospheric Research (NCAR) were the sources for the sea-level-pressure and 500-mbar geopotential-height images. All images are in GIF files (1024 × 822 pixels, 256 colors) and can be displayed on many different computer platforms. Each annual subdirectory contains 141 images, each seasonal subdirectory contains 563 images, and each monthly subdirectory contains 1656 images. The entire atlas requires approximately 340 MB of disk space, but users may retrieve any number of images at one time.

Users should have monitors with the capability of displaying 256 colors (SVGA, 8-bit RGB color) and software for viewing GIF files. The monitor is necessary to take advantage of the high-resolution color images and to display them correctly. For users needing a GIF viewer, three shareware viewers are provided—one for an IBM-compatible PC, one for a Macintosh, and one for a workstation.

A CD-ROM version of the atlas is available for \$30.00. For a copy of the CD-ROM, send your name and address to Frank Keimig, Department of Geology and Geography, University of Massachusetts, Amherst, MA 01003-5820 or email address frank@climate1.geo.umass.edu.

DB1004 Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data

T. R. Karl, R. G. Baldwin, M. G. Burgin, D. R. Easterling, R. W. Knight, and P. Y. Hughes (contributors)

This database is a companion to the Historical Climatology Network (HCN) database for the contiguous United States (see NDP019/R3 on page 92). The database contains monthly temperature (minimum, maximum, and mean) and total monthly precipitation data for 47 Alaskan stations. These data were derived from a variety of sources including the National Climatic Data Center archives, the state climatologist for Alaska, and published literature. The period of record varies by station. The longest record is for the Sitka Magnetic Observatory (1828) and most records extend through 1990. Unlike the HCN database for the contiguous U.S., adjustments have not been made to these climate records for time-of-observation differences, instrument changes, or station moves. The data are in three files [one data file that contains all four climate variables, one station inventory file, and one station history file]. The file sizes range from 3.5 kB to 1.7 MB.

FORAST Database

DB1005

S. B. McLaughlin, D. J. Downing, T. J. Blasing, B. L. Jackson, D. J. Pack, D. N. Duwick, L. K. Mann, and T. W. Doyle (contributors)

The Forest Responses to Anthropogenic Stress (FORAST) project was designed (1) to determine whether evidence of alterations of long-term growth patterns of several species of eastern forest trees was apparent in tree-ring chronologies from within the region and (2) to identify environmental variables that were temporally or spatially correlated with any observed changes. The project was supported principally by the U.S. Environmental Protection Agency (EPA) with additional support from the National Park Service.

The FORAST project was initiated in 1982 as exploratory research to document patterns of radial growth of forest trees during the previous 50 or more years within 15 states in the northeastern United States. Radial growth measurements from more than 7000 trees are provided along with data on a variety of measured and calculated indices of stand characteristics (basal area, density, and competitive indices); climate (temperature, precipitation, and drought); and anthropogenic pollutants (state and regional emissions of SO₂ and NO_x, ozone monitoring data, and frequency of atmospheric-stagnation episodes and atmospheric haze). These data were compiled into a single database to facilitate exploratory analysis of tree growth patterns and responses to local and regional environmental conditions.

The database files are divided into three groups. Two of the groups (FORASTR and FORAST) contain the same tree-ring chronology information (ring-width and basal area increments); one is sorted by region, and the other by tree species. The third group (FORASTEC) is a collection of miscellaneous background data including climate, air quality, and tree and site characteristics.

The database consists of 99 data files. The original 48 SAS data files are provided and require approximately 111 MB of disk space. In addition, CDIAC has created 48 ASCII files of the same data, an ASCII README file, region file, and species file. The region and species files merge all the files in the respective subdirectory. Hardcopy documentation describing the experimental protocols used and the format of the database files is available from CDIAC.

Portions of the FORAST database have been incorporated into the International Tree-Ring Data Base (ITRDB), a large collection of tree-ring data archived by and available from the National Geophysical Data Center (NGDC). For further information about the ITRDB, contact Bruce Bauer at NGDC (303-497-6280 or bab@luna.ngdc.noaa.gov).

Goddard Institute for Space Studies (GISS) 3-Dimensional (3-D) Global Tracer Transport Model

DB1006

I. Fung (contributor)

This directory contains the input files used in simulations of atmospheric CO₂ using the GISS 3-D global tracer transport model. The directory contains 16 files including a help file (CO2FUNG.HLP), 12 files containing monthly exchanges with vegetation and soils (CO2VEG.JAN . . . DEC), 1 file containing releases of CO₂ from fossil fuel burning (CO2FOS.MRL), 1 file containing releases of CO₂ from land transformations (CO2DEF.HOU), and 1 file containing the patterns of CO₂ exchange with the oceans (CO2OCN.TAK).

**DB1007 Atmospheric Methane at Cape Meares, Oregon, U.S.A.:
A High-Resolution Data Base for the Period 1979–1992**

M. A. K. Khalil and R. A. Rasmussen (contributors)

This data base presents continuous automated atmospheric methane (CH_4) measurements taken at the atmospheric monitoring facility in Cape Meares, Oregon, by the Oregon Graduate Institute of Science and Technology. The Cape Meares data represent some 119,000 individual atmospheric methane measurements carried out during 1979–1992. Analysis of ambient air (collected 12 to 72 times daily) was carried out by means of an automated sampling and measurement system, using the method of gas chromatography and flame ionization detection. Despite the long course of the record and the large number of individual measurements, these data may all be linked to a single absolute calibration standard.

The data are contained in three files. The largest file (2.14 MB) contains all individual atmospheric methane measurements, collected at Cape Meares over the period January 1979–January 1992. A second file (189 kB) contains daily average concentrations of methane, sampling statistics, and interpolations for days when data were not taken. The last file (10 kB) contains monthly averages (derived from the individual and daily data) and statistics of dispersion, calculated by three different methods: the arithmetic mean (along with 90% confidence limits), the median (along with 5th and 95th percentile values), and a middle value (also with accompanying 90% confidence limits) based on a non-parametric statistical method.

**DB1008 Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global
Cooperative Air Sampling Network, 1983–1993**

E. J. Dlugokencky, P. M. Lang, K. A. Masarie, and L. P. Steele (contributors)

This data base presents atmospheric methane (CH_4) mixing ratios from flask air samples collected over the period 1983–1993 by the National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory's (NOAA/CMDL's) global cooperative air sampling network. Air samples were collected approximately once per week at 44 fixed sites (37 of which were still active at the end of 1993). Samples were also collected at 5 degree latitude intervals along shipboard cruise tracks in the Pacific Ocean between North America and New Zealand (or Australia) and at 3 degree latitude intervals along cruise tracks in the South China Sea between Singapore and Hong Kong. The shipboard measurements were made approximately every 3 weeks per latitude zone by each of two ships in the Pacific Ocean and approximately once every week per latitude zone in the South China Sea. All samples were analyzed for CH_4 at the NOAA/CMDL laboratory in Boulder, Colorado, by gas chromatography with flame ionization detection, and each aliquot was referenced to the NOAA/CMDL methane standard scale.

In addition to providing the complete set of atmospheric CH_4 measurements from flask air samples collected at the NOAA/CMDL network sites, this data base also includes files which list monthly mean mixing ratios derived from the individual flask air measurements. These monthly summary data are available for 35 of the fixed sites and 21 of the shipboard sampling sites.

The data for the complete set of individual measurements are contained in 85 files, ranging in size from 2.7 kB to 187 kB and totaling 2.7 MB. Two additional files contain the monthly summary data.

One of these files (30.2 kB) contains all monthly mean methane values for NOAA/CMDL fixed monitoring sites. The second file (14.3 kB) contains all monthly mean methane values for NOAA/CMDL shipboard sites. An additional file (151.0 kB) contains a PostScript image showing the locations of all fixed sampling sites in the NOAA/CMDL cooperative air sampling network; also shown are the approximate sampling locations from ocean vessels participating in the shipboard sampling program. The data and accompanying descriptive material are available in electronic form only; hard copy documentation is not available.

Intergovernmental Panel on Climate Change (IPCC), Working Group 1, 1994: Modelling Results Relating Future Atmospheric CO₂ Concentrations to Industrial Emissions

DB1009

I. G. Enting, T. M. L. Wigley, and M. Heimann (eds.)

This database contains the results of various projections of the relation between future CO₂ concentrations and future industrial emissions. These projections were contributed by groups from a number of countries as part of the scientific assessment for the report, "Radiative Forcing of Climate Change" (1994), issued by Working Group 1 of the Intergovernmental Panel on Climate Change. There were three types of calculations: (1) forward projections, calculating the atmospheric CO₂ concentrations resulting from specified emissions scenarios; (2) inverse calculations, determining the emission rates that would be required to achieve stabilization of CO₂ concentrations via specified pathways; (3) impulse response function calculations, required for determining Global Warming Potentials. The projections were extrapolations of global carbon cycle models from pre-industrial times (starting at 1765) to 2100 or 2200 A.D. There were two aspects to the exercise: (1) an assessment of the uncertainty due to uncertainties regarding the current carbon budget, and (2) an assessment of the uncertainties arising from differences between models. To separate these effects, a set of standard conditions was used to explore inter-model differences and then a series of sensitivity studies was used to explore the consequences of current uncertainties in the carbon cycle.

The contents of this data base are found in three subdirectories: "inputs", "results", and "report". The "inputs" subdirectory (11 files totaling 130 kB) contains the empirical time series data that were used as the basis of the modelling projections. These data include historical and modern measurements of atmospheric CO₂ concentrations, CO₂ emissions from industry and land-use changes, and ¹⁴C activities for atmospheric CO₂. The "results" subdirectory (46 files totaling 1.02 MB) contains the projections (as time series) contributed by 10 groups of carbon cycle modelers. The categories of data in this subdirectory include (1) projected CO₂ concentrations for specified emissions scenarios, (2) ocean CO₂ fluxes for specified regimes of emissions or atmospheric concentrations, and (3) industrial emissions (from inverse calculations) for specified concentration time series (i.e., stabilization pathways). The "report" subdirectory (8 files totaling 4.45 MB) contains a set of PostScript files that constitute the report "Future Emissions and Concentrations of Carbon Dioxide: Key Ocean/Atmosphere/Land Analyses" (CSIRO Division of Atmospheric Research, Technical Paper No. 31). This report details the specifications for the modelling projections, the models that were used, and the results that were obtained.

DB1010 Globally Averaged Atmospheric CFC-11 Concentrations: Monthly and Annual Data for the Period 1975–1992

M. A. K. Khalil and R. A. Rasmussen (contributors)

This data set presents globally averaged atmospheric concentrations of chlorofluorocarbon 11, known also as CFC-11 or F-11 (chemical name: trichlorofluoromethane; formula: CCl_3F). The monthly global average data are derived from flask air samples collected at eight sites in six locations over the period August 1980–July 1992. The sites are Barrow (Alaska), Cape Mearns (Oregon), Cape Kumukahi and Mauna Loa (Hawaii), Cape Matatula (American Samoa), Cape Grim (Tasmania), Palmer Station, and the South Pole (Antarctica). At each collection site, monthly averages were obtained from three flask samples collected every week.

In addition to the monthly global averages available for 1980–1992, this data set also contains annual global average data for 1975–1985. These annual global averages were derived from January measurements at the South Pole and in the Pacific Northwest of the United States (specifically, Washington state and the Oregon coast).

The data are contained in a single 1.8 kB file and are located in the subdirectory /pub/db1010.

DB1011 Atmospheric Carbon Monoxide Mixing Ratios NOAA Climate Monitoring and Diagnostics Laboratory Cooperative Air Sampling Network, 1988–1993

P. C. Novelli and K. A. Masarie (contributors)

Individual site files provide CO mixing ratios in parts per billion (ppb) (ppb = parts in 10^9 by mole fraction) on the basis of measurements from the NOAA/CMDL Cooperative Air Sampling Network. Data are provided through June 1993 for stations at which the first sample was collected before July 1991. The report includes a list of locations from which samples of air were collected and analyzed for CO and a listing of all sites in the air sampling network used for CO measurements (as of 9/94). The latter listing, which is in the form of a table, includes the three letter code used to identify each site, the location of the site, latitude and longitude (in degrees and minutes), the altitude of the sampling location (in meters above mean sea level), the start and end dates for sampling CO, the country, and the cooperating agency. Sampling frequencies are approximately weekly for the fixed sites and average one sample every 3 weeks per latitude zone for PAW and OPC and about one sample every week per latitude for SCS. The air samples are collected by two general methods: (1) flushing and then pressurizing glass flasks with a pump or (2) opening a stopcock on an evacuated glass flask. During each sampling event a pair of flasks is filled in series.

All samples were analyzed for CO at the NOAA/CMDL laboratory in Boulder by gas chromatography with mercuric oxide reduction detection, and all measurements are referenced to the CMDL CO scale.

A Global 1 Degree by 1 Degree Distribution of Atmospheric/Soil CO₂ Consumption by Continental Weathering and of Riverine HCO₃ Yield

DB1012

P. A. Suchet and J.-L. Probst (contributors)

The mission of the Centre National de la Recherche Scientifique (CNRS) of Strasbourg Cedex, France, is to study "The Global Carbon Cycle and its Perturbation by Man and Climate, the Terrestrial Biosphere." With the support of the Environment Programme of the European Communities, modeling of the spatial distribution of atmospheric-soil CO₂ consumption by chemical weathering of continental rocks has been and is being conducted. One of the major results of these studies is a set of global maps which show the distribution of CO₂ consumption (FCO₂) and the transport of bicarbonate (FHCO₃⁻) from rivers to the ocean, each in moles per kilometer squared per year (mol km²/year).

This database contains estimates of the net flux of atmospheric-soil CO₂ (FCO₂) produced by a model by Amiotte Suchet and Probst and the associated bicarbonate river flux (FHCO₃⁻). These variables are referenced to a 1 degree latitude by 1 degree longitude world grid. The grid contains 64,800 records (i.e., grid cells) originating at -180° W by -90° N and extending to 180° W by 90° N.

Global and Latitudinal Estimates of δ¹³C from Fossil-Fuel Consumption and Cement Manufacture

DB1013

R. J. Andres, G. Marland, and S. Bischof (contributors)

This database contains estimates of the annual mean value of δ¹³C of CO₂ emissions from fossil-fuel consumption and cement manufacture for 1860-1992. It also contains estimates of the value of δ¹³C for 1° latitude bands for the years 1950, 1960, 1970, 1980, 1990, 1991, and 1992. These estimates of the carbon isotopic signature account for the changing mix of coal, petroleum, and natural gas being consumed and for the changing mix of petroleum from various producing areas with characteristic isotopic signatures. This time series of fossil-fuel δ¹³C signature provides an additional constraint for balancing the sources and sinks of the global carbon cycle and complements the atmospheric δ¹³C measurements that are used to partition the uptake of fossil carbon emissions among the ocean, atmosphere, and terrestrial biosphere reservoirs. The data are in two files ranging in size from 2.8 to 12.9 kB.

DB1014 *In situ* Carbon 13 and Oxygen 18 Ratios of Atmospheric CO₂ from Cape Grim, Tasmania, Australia: 1982–1993

R. J. Francey, P. P. Tans, C. E. Allison, I. G. Enting, J. W. C. White, and M. Troler (contributors)

Since 1982, a continuous program of sampling atmospheric CO₂ to determine stable isotope ratios has been maintained at the Australian Baseline Air Pollution Station, Cape Grim, Tasmania (40° 40'56" S, 144° 41'18" E). This program uses a unique combination of factors with respect to obtaining a globally representative signal from a surface site: the process of *in situ* extraction of CO₂ from air, the preponderance of samples collected in conditions of strong wind from the marine boundary layer of the Southern Ocean, and the determination of all isotope ratios relative to a common high-purity CO₂ reference gas with isotopic $\delta^{13}\text{C}$ close to atmospheric values. Air samples are collected during baseline condition episodes at a frequency of around one sample per week. Baseline conditions are characterized by wind direction in the sector 190°–280°, condensation nucleus concentration below 600/cm³, and steady continuous CO₂ concentrations (variation ± 0.2 ppmv/hour). Mass spectrometer analyses for $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ are carried out by CSIRO's Division of Atmospheric Research in Aspendale, usually one to three weeks following collection.

This record is possibly the most accurate representation of global atmospheric ¹³C behavior over the last decade and may be used to partition the uptake of fossil-fuel carbon emissions between ocean and terrestrial plant reservoirs. The database consists of two files, a descriptive "readme" file (153 lines) and a data file ("isotope.cgo," 440 lines) that contains the *in situ* ¹³C and ¹⁸O ratios of atmospheric CO₂ from Cape Grim for 1982 through 1993.

DB1015 Global Patterns of Carbon Dioxide Emissions from Soils on a 0.5 Degree Grid Cell Basis

J. W. Raich and C. S. Potter (contributors)

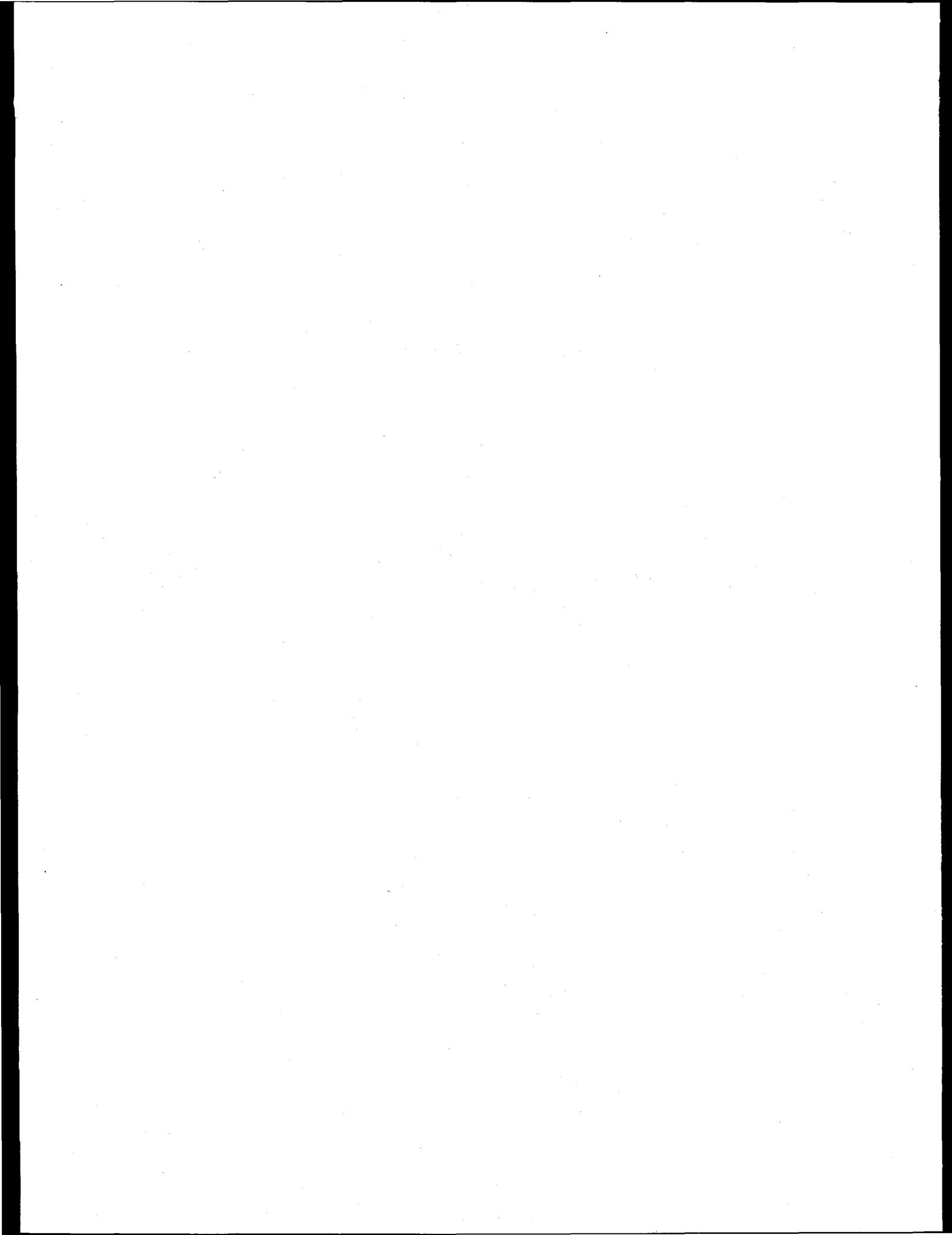
Semi-mechanistic, empirically-based statistical models were used to predict the spatial (0.5 degree grid cells) and temporal (monthly and annual) patterns of global carbon emissions from terrestrial soils. Emissions include the respiration of both soil organisms and plant roots. Geographically referenced data of mean monthly air temperature and precipitation, soil organic carbon and nitrogen content, soil type and natural vegetation type were used in the model development. It was found that at the global scale the rates of soil CO₂ efflux correlate significantly with temperature and precipitation, have a pronounced seasonal pattern in most locations, and contribute to observed wintertime increases in atmospheric CO₂.

The DB1015 data are the predicted CO₂ emissions of the model based on untransformed precipitation data and the exponential relationship between soil biological activity and temperature. The data at the 0.5° latitude by longitude spatial and monthly temporal resolution represents the best resolved estimate to date of global CO₂ fluxes from soils and should facilitate investigations of net exchanges between the atmosphere and terrestrial biosphere.

The data files (~10 MB total) consist of 12 monthly and one annual model output files, one geographic information file and a Read-Me file with simple FORTRAN data access information.

Section H

USDA Reports on Response of Vegetation to Carbon Dioxide



Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980

DA001

H. H. Rogers, G. E. Bingham, J. D. Cure, W. W. Heck, A. S. Heagle, D. W. Israel, J. M. Smith, K. A. Surano, and J. F. Thomas

During the summer of 1980 techniques were developed for the generation of large-scale test atmospheres in the field. These methods are applicable to the study of CO₂ dose-response relationships of agronomic and forest species. The system performed satisfactorily and its feasibility for the study of responses of field vegetation to CO₂ was demonstrated.

Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981

DA003

L. H. Allen, Jr., K. J. Boote, J. W. Jones, J. W. Mishoe, P. H. Jones, C. V. Vu, R. Valle, and W. J. Campbell

Part A of this report describes responses of soybean crops that were grown from seeding to final harvest in outdoor, controlled environment chambers, Soil-Plant-Atmosphere- Research (SPAR) units, that were used to conduct experiments at CO₂ concentrations from 330 vpm to 800 vpm. This report also contains information on plant growth, staging, and components of dry matter at final harvest, as well as preliminary information on leaf RuBP carboxylase. Part B of this report includes laboratory analyses of nonstructural carbohydrates and nitrogen of leaves during diurnal samplings, and of plant components of the final harvest (leaves, stems, petioles, seed).

Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985

DA022

P. K. Biswas, J. R. Allen, N. C. Bhattacharya, J. Y. Lu, R. D. Pace, H. H. Rogers, K. B. Coleman, J. F. Eatman, P. P. Ghosh, N. Mbikayi, J. N. McCrimmon, and A. Menefee

This report summarizes the results of a study on the physiological and biochemical effects of enriched CO₂ on sweet potatoes and cowpeas. The following are the results of the study.

Sweet potatoes grown in the open top chambers, at ambient CO₂ concentrations had fewer leaves, less total runner length, and lower fresh and dry weights of shoots, leaves, and tubers as compared with sweet potatoes grown in the open field without chambers. While shoot growth in sweet potatoes increased with increasing CO₂, few of the effects were large enough to be significant, but the percentages of nitrogen and protein nitrogen in sweet potato leaves decreased significantly at higher CO₂ concentrations. The total fresh weight of tubers increased significantly at the higher levels of CO₂, primarily due to an increase in the number of tubers. There were no differences in the density of stomates or in stomatal conductances in sweet potato leaves. Protein, total carotenoids, and insoluble dietary fiber of tubers all decreased with increasing CO₂, while dry matter content increased with increasing CO₂.

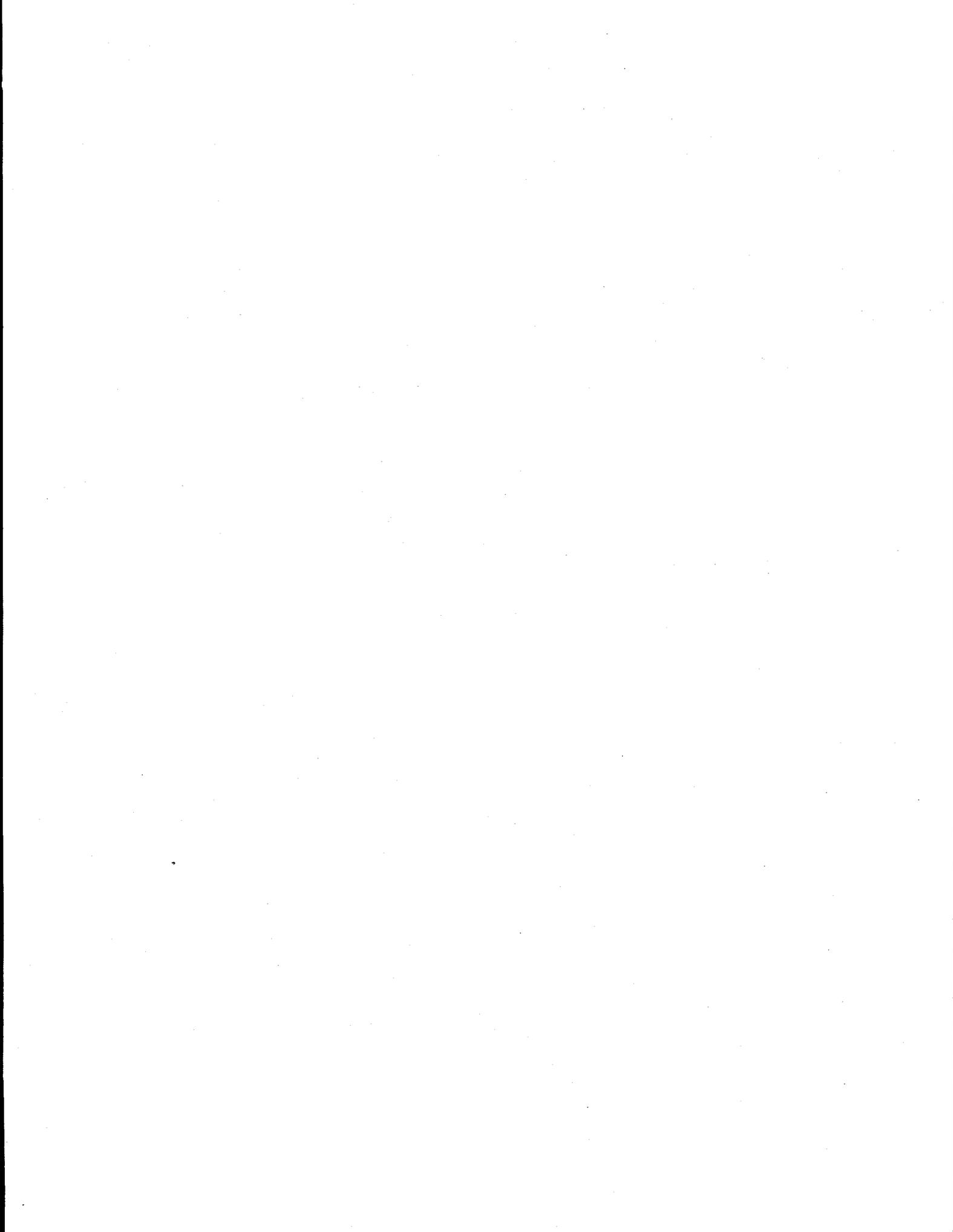
In phytotron studies with pot-grown sweet potatoes, plants grown at 675 or 1000 ppm CO₂ showed increases in the length of the main stem, total branch length, the number of branches, and leaf area as compared with those grown in 350 ppm CO₂. At each harvest interval the production of total dry matter increased in response to increasing CO₂. Specific leaf weight also increased with increased CO₂ concentrations. At the final harvest, the dry weights of roots and tubers increased 1.8 and 2.6 times in plants grown at 675 and 1000 ppm CO₂, respectively, compared with those grown at 350 ppm CO₂. The number and size of tubers increased at high CO₂ concentrations. Carbon dioxide enrichment resulted in early tuber maturation in sweet potatoes.

Cowpeas were studied in two experiments in open top chambers. In the row crops study, the fresh and dry weights of cowpea plants grown in chambers at ambient CO₂ were slightly lower than in plants grown in the open field, but the differences were statistically insignificant. Within chambers, the fresh and dry weights of plants were significantly greater at 506 and 655 ppm CO₂ as compared to plants grown at ambient CO₂ (354 ppm). The number of leaves, leaf area, plant height, number of nodules and pods, and the fresh weight of seeds were significantly greater at enriched CO₂ levels. Protein nitrogen of seeds increased significantly with increased CO₂ concentrations. The number of stomata did not differ among the different chambers. Stomatal conductances were significantly greater in plants grown at 506 ppm CO₂ than in plants grown in chambers at ambient CO₂.

In the cowpea pot study, plants grown at elevated CO₂ had greater dry weights of seeds and vegetative parts and produced more leaves than plants grown in a chamber at ambient CO₂, but there were not differences in plant height or rate of growth. Differences in the number of nodules and the rate of nitrogen fixation were not significant, but nitrogen fixation rates in plants grown at elevated CO₂ were approximately 45% higher, on a per plant basis, than in plants grown in ambient chambers. In phytotron studies with pot-grown cowpeas, the length of the main stem and branches, the number of leaves and leaf area were greater at 675 and 1000 ppm CO₂ than at 350 ppm CO₂. Flowers appeared 10-12 days earlier in an enriched CO₂ atmosphere. Carbon dioxide enrichment hastened pod and seed formation in cowpeas and also caused greater partitioning of biomass into pods than into roots, stems, or leaves. Total seed weight and number of seeds per pod were significantly greater at elevated CO₂, but CO₂ enrichment did not affect the harvest index of cowpeas.

Section I

Other Publications



**Workshop on Environmental and Societal Consequences of a Possible
CO₂-Induced Climate Change** 009
(CONF-7904143, October 1980)

Office of Health and Environmental Research, U.S. Department of Energy

This is a report of a workshop held in April 1979, at Annapolis, Maryland. This was one of the major events in the development of the Department of Energy's research program on the carbon dioxide issue. The workshop was on the development of the program on the environmental and societal consequences resulting from a climate change and increase in atmospheric concentrations of carbon dioxide.

**Proceedings of the Carbon Dioxide and Climate Research Program
Conference** 011
(CONF-8004110, December 1980)

L. E. Schmitt (ed.)

This is a report of a conference held in Washington, D.C., in April 1980, to review research progress through fiscal year 1979 of the DOE's Carbon Dioxide and Assessment Program, and to review a draft update of the Comprehensive Plan, Part I: The Global Carbon Cycle and Climatic Effects of Increasing Carbon Dioxide (subsequently issued as document 008).

Flux of Organic Carbon by Rivers to the Oceans 016
(CONF-8009140, April 1981)

Committee on Flux of Organic Carbon to the Oceans, National Research Council

The state of knowledge about the role of rivers in the transport, storage, and oxidation of carbon is the subject of this report. It summarizes a workshop of the Committee on Flux of Organic Carbon to the Ocean, Division of Biological Sciences, National Research Council held at Woods Hole, Massachusetts on September 1980.

Workshop on Oceanic CO₂ Standardization 017
(CONF-7911173, February 1982)

H. G. Ostlund and D. Dyrssen (eds.)

This report contains detailed information on the measurements of carbon dioxide and alkalinity made during the GEOSECS (Geochemical Ocean Section) program.

024

Workshop on Sea Level Rise and Coastal Processes

(DOE/NBB-0086, March 1989)

A. J. Mehta and R. M. Cushman (eds.)

The possibility in the coming decades of a higher rate of relative sea-level rise globally is now thought to be sufficiently great to warrant serious consideration for its potential implications to human populations. However, the complexities of shoreline response to sea-level rise are contingent on a wide range of interrelationships between physical and ecological factors. The question of how shorelines and shore environments will change with sea-level rise must ultimately focus on our capability to predict such changes, which in turn requires an understanding of the processes involved and availability of data.

As a first step, the University of Florida (UF) undertook a study during the summer of 1987, which resulted in a report, "Some Considerations on Coastal Processes Relevant to Sea Level Rise," by Ashish Mehta, Robert Dean, William Dally, and Clay Montague. In this report, the effects of potential sea-level rise on the shoreline and shore environment were briefly examined by considering the interactions between sea-level rise and coastal processes.

Considerations amply demonstrated the complexities of the interaction between sea-level change and loose-boundary shoreline, their site-specificity, and the inadequacy of inundation models. It was concluded that, with some minor exceptions, the basic knowledge of coastal processes—including hydrodynamics, sedimentary processes, and their interaction, and the available data base are inadequate for predictive modeling. Apart from difficulties in modeling boundary layer turbulence and associated mixing processes, sediment transport formulations require knowledge of a host of free coefficients that tend to be highly site-specific and, therefore, difficult to evaluate in the complex coastal environment. Besides further improvements in theory, and the need for better definition of wave forcing through adequate long-term monitoring of the coastal wave field via field measurement is emphasized.

To critique the conclusions of the UF report and to reach a broader agreement on research needs to vastly improve the capability to predict shoreline response, the "Workshop on Sea Level Rise and Coastal Processes" was held at Palm Coast, Florida, in March 1988. The report on the workshop includes a version of the UF report (modified by its authors after the workshop) and an appendix. The appendix contains comments by workshop participants, excluding the authors of the UF report. In addition, the appendix includes the comments of John de Ronde, who was invited to the workshop to present his view of the Dutch experience, which provide insight into what higher relative sea level might mean worldwide.

Participants comments largely reinforce the conclusions of the UF report through additional illustrative examples, clarifications, and qualifications, in some cases.

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Asymmetric Change of Daily Temperature Range

(Conf. 9309350, April 1994)

G. Kukla, T. R. Karl, and M R. Riches (eds.)

This document presents the results of 37 scientists from ten countries who looked into the character of current global warming. They confirmed the earlier finding of Karl et al. (1993),

namely that more of the warming is occurring at night than during the day. As a result, the diurnal temperature range (DTR) is decreasing over a major part of the studied land surfaces, although areas of opposite trends were also detected. Additional observations of the phenomenon were presented at the meeting and its causes and potential impacts discussed.

CO₂ Symposium

BERN

Published by the American Geophysical Union

This report presents papers given at the symposium held in September 1981, at the University of Bern, Switzerland. The participants were scientists directly responsible for making atmospheric carbon dioxide measurements or were involved in interpreting these measurements. A large body of new atmospheric CO₂ data, supplemented by isotopic and oceanic measurements, were presented at the conference.

A Report from the Second U.S./Japan Workshop on Global Change Research: Environmental Response Technologies (Mitigation and Adaptation) (February 1993)

**CONF-
930285**

Sylvia Edgerton, National Science Foundation

Tateki Mizuno, National Institute for Resources and Environment (Japan)

The second U.S.-Japan Workshop on Global Change was planned and organized under the aegis of the U.S./Japan Science and Technology (UJST) Agreement. The High-Level Committee for the UJST decided in 1989 to support the conduct of U.S./Japan workshops to encourage joint research on high-priority scientific and technical questions related to global change. The second global change workshop under UJST was hosted by the U.S. Committee on Earth and Environmental Sciences (CEES) in February 1993, and held at the East-West Center, in Honolulu, Hawaii. The subject of the workshop was Environmental Response Technologies (Mitigation and Adaptation).

Proceedings of the International Symposium on Ecological Aspects of Tree Ring Analysis (April 1987)

**CONF-
8608144**

G. C. Jacoby, Jr. and J. W. Hornbeck (eds.)

The objective of this proceedings of the meeting is to aid communications within the field of tree-ring analysis, stimulate others to see the potential for even more applications, and serve as a resource for those entering the field.

**CONF-
9006134**

**Global Climate Feedbacks: Proceedings of the Brookhaven
National Laboratory Workshop**
(June 1990)

B. Manowitz (ed.)

The present General Circulation Models (GCMs) do not model important feedbacks, including those from clouds, oceans, and land processes. The purpose of this workshop was to identify such potential feedbacks, to evaluate the uncertainties in the feedback processes (and, if possible, to parameterize the feedback processes so that they can be treated in a GCM), and to recommend research programs that will reduce the uncertainties in important feedback processes.

The following papers were presented:

- "Observational Determination of the Greenhouse Effect," A. Raval and V. Ramanathan
- "Interpretation of Cloud-Climate Feedback as Produced by 14 Atmospheric General Circulation Models," R. D. Cess
- "Cloud Parameterization," D. A. Randall
- "Comments on Atmospheric Feedbacks," A. Heymsfield
- "Atmospheric Feedbacks: Comments," S. E. Schwartz
- "Ocean Thermal Transients: A Program of Data Analysis, Modeling, and Monitoring of the Atlantic Ocean Thermohaline Circulation," K. Bryan
- "Paleo Deep Water Variability: Magnitude and Rapidity," E. A. Boyle
- "Role of the Ocean Carbon Cycle in Determining Atmospheric pCO₂," J. L. Sarmiento
- "Comments on the Problem of Ocean Circulation," C. Wunsch
- "Elements of Oceanic CO₂ Feedback in Response to Climate Change," T. Takahashi
- "Terrestrial Ecosystems and Climatic Change," W. R. Emanuel and D. S. Schimel
- "The Response of Ecosystems to Global Change: Research Agenda," F. A. Bazzaz
- "Sea Ice Response to Global Climate Change," W. D. Hibler III
- "Commentary on Sea Ice Feedbacks," R. E. Moritz

**NCAR/TN-
201 + STR**

**Atlas of Simultaneous Occurrence of Different Cloud Types Over
the Ocean**
(November 1982) (Reprinted 1990)

C. J. Hahn, Cooperative Institute for Research in Environmental Sciences

S. G. Warren, University of Washington

J. London, University of Colorado

R. M. Chervin and R. Jenne, National Center for Atmospheric Research

The importance of clouds for the earth's radiation budget is receiving a great deal of attention in current atmospheric research. This includes both studies of the mechanisms of cloud formation and theoretical and experimental work on radiative properties of clouds. Recognition of the importance of clouds for global and regional climate has led to the plan for the International Satellite Cloud Climatology Project (ISCCP). Preparation for the five-year project is now under way, in that the methods for obtaining cloud information from satellite radiation observations are

being developed. This atlas of co-occurrence of different cloud types over the ocean is expected to aid in the development of these methods by providing ground-based data for comparison with satellite observations. It should also assist the development of cloud-generation schemes in climate models.

Cloud observations from ships are used to investigate the co-occurrence of different cloud types and the geographical and seasonal variation of these co-occurrences. Ground-based observations are used because they provide a more definitive identification of clouds by type than do satellite observations. The clouds are grouped into six types (cirrus-type clouds, altostratus + altocumulus, nimbostratus, cumulus, stratus + stratocumulus, and cumulonimbus). The results are expressed as contingency probabilities; that is, given that one cloud type is present, the probability that another particular type is also present is computed. Since higher clouds are detectable only when the lower clouds are not overcast, a procedure is developed to remove the resulting bias by computing the co-occurrence probabilities. Thus both upward-directed (e.g., cumulus implies cirrus) and downward-directed (e.g., cirrus implies cumulus) contingency probabilities should be reasonably accurate. Maps of these quantities, as well as of the overall frequency of occurrence of each cloud type, of fog, and of clear sky, are presented at 15° latitude by 30° longitude resolution. These contingency probabilities should be useful for testing cloud-generation algorithms in general circulation models and for interpretation of cloud observations from satellites.

Atlas of Simultaneous Occurrence of Different Cloud Types Over Land

(August 1984) (Reprinted 1990)

NCAR/TN-241 + STR

C. J. Hahn, Cooperative Institute for Research in Environmental Sciences

S. G. Warren, University of Washington

J. London, University of Colorado

R. M. Chervin and R. Jenne, National Center for Atmospheric Research

This is the second of a series of atlases to be published as part of an extensive study of the global cloud climatology from ground-based observations. This first atlas, published as NCAR/TN-201 + STR, described the observed simultaneous occurrence of different cloud types over the oceans. The present atlas covers a similar analysis of cloud observations over the land. The classification and grouping of cloud types, and the general methodology of determining different cloud type co-occurrences was discussed in the first atlas, and the reader is referred to that atlas for details of the procedures used. Additional discussion is contained in the present atlas to describe those cases where a different procedure was followed either as an improvement, or to fit the different circumstances under which land-based cloud observations are made.

The current cloud climatology study is part of the International Satellite Cloud Climatology Program (ISCCP) and will provide a complementary data set for evaluating and validating results from the First ISCCP Regional Experiment (FIRE) and subsequent field experiments.

The Global Carbon Cycle

(January 1991)

Carbon Dioxide Research Program, U.S. Department of Energy

This reprint from the *Canadian Journal of Forest Research* features research directed through Oak Ridge National Laboratory's Center for Global Environmental Studies, Environmental Sciences Division.

Featured articles and contributing researchers include:

- "Estimating the effects of land-use change on global atmospheric CO₂ concentrations," by V. H. Dale, R. A. Houghton, and C. A. S. Hall;
- "Historical analysis of changes in land use and carbon stock of vegetation in south and southeast Asia," by E. P. Flint and J. F. Richards;
- "Biomass of tropical forests of south and southeast Asia," by S. Brown, A. J. R. Gillespie, and A. E. Lugo;
- "Refining estimates of carbon released from tropical land-use change," by C. A. S. Hall and J. Uhlig; and
- "Releases of carbon to the atmosphere from degradation of forests in tropical Asia," by R. A. Houghton.

Natural Sinks of CO₂

J. Wisniewski, Wisniewski & Associates, Inc.

A. E. Lugo, Institute of Tropical Forestry

To evaluate the global carbon budget and the potential for managing the Earth's carbon sinks, a workshop of leading scientists was convened in Palmas Del Mar, Puerto Rico, in February 1992.

The workshop was motivated by needs to (1) understand properties, processes and magnitudes of natural sinks of atmospheric CO₂; (2) expand the scope of measurements and models to provide a truly interdisciplinary analysis of the global carbon cycle; (3) encourage broad participation (academic, government and private sector) in research that offers solutions to increasing atmospheric CO₂; and (4) balance the carbon budget as a basis for better policy making.

This statement is a synopsis of findings presented at the workshop. New information was presented at the workshop that indicated substantial potential exists for capturing and sequestering carbon in land and water environments. Carbon is being absorbed by natural sinks, and it is economically feasible to manage additional land, soil, and coastal ecosystems with the objective of building carbon stocks.

Note: This is a promotional/descriptive flyer for Kluwer Academic Publishers, publishers of the proceedings of this workshop. This is a summary and should not be construed as an endorsement.

CDIAC Fact Sheets

Compiled by F. W. Stoss

Fact sheets are short, descriptive materials promoting the availability of specific information products or services. Fact sheets appearing on this list are periodically updated and new fact sheets are added in response to request-response activities. An order form is provided to request future editions.

ARM Outreach Factsheet gives a brief description of the research and program activities of the U.S. Department of Energy's Atmospheric Radiation Measurement Program. An order form is provided to request future issues. (see p. 136).

Carbon Dioxide Information Analysis Center (CDIAC) Factsheet gives a brief history and description of CDIAC activities.

CDIAC Communications Factsheet gives a brief description of the newsletter and has an order form to request future issues. (see p. 136).

DOE Research Summary: A Synopsis of DOE-Sponsored Research Factsheet describes the 4-page newsletter that highlights current research funded by DOE's Global Change Research Program. An order form is provided to request future issues. (see p. 136).

Environmental Policy and Impacts to International Commerce and Trade—Selected Resources Factsheet lists publications and organizations for further environmental information.

Glossary: Carbon Dioxide and Climate Factsheet briefly describes the glossary of selected CO₂ terms available from CDIAC. (see p. 77).

Office of Scientific and Technical Information (OSTI) Factsheet describes a number of information management tools available from them. An order form is provided.

Specialty Newsletters: Global Studies and Climate Change Factsheet is a compilation of newsletters that cover the issues of global change. An order form is provided.

Technical Assistance for Developing Regions Factsheet gives information about two programs established to assist developing regions resolve global environmental problems.

Trends Factsheet describes data in Trends issues from the 1990 inaugural issue to the latest version *Trends '93: A Compendium of Data on Global Change*. (see p. 81).

Newsletters

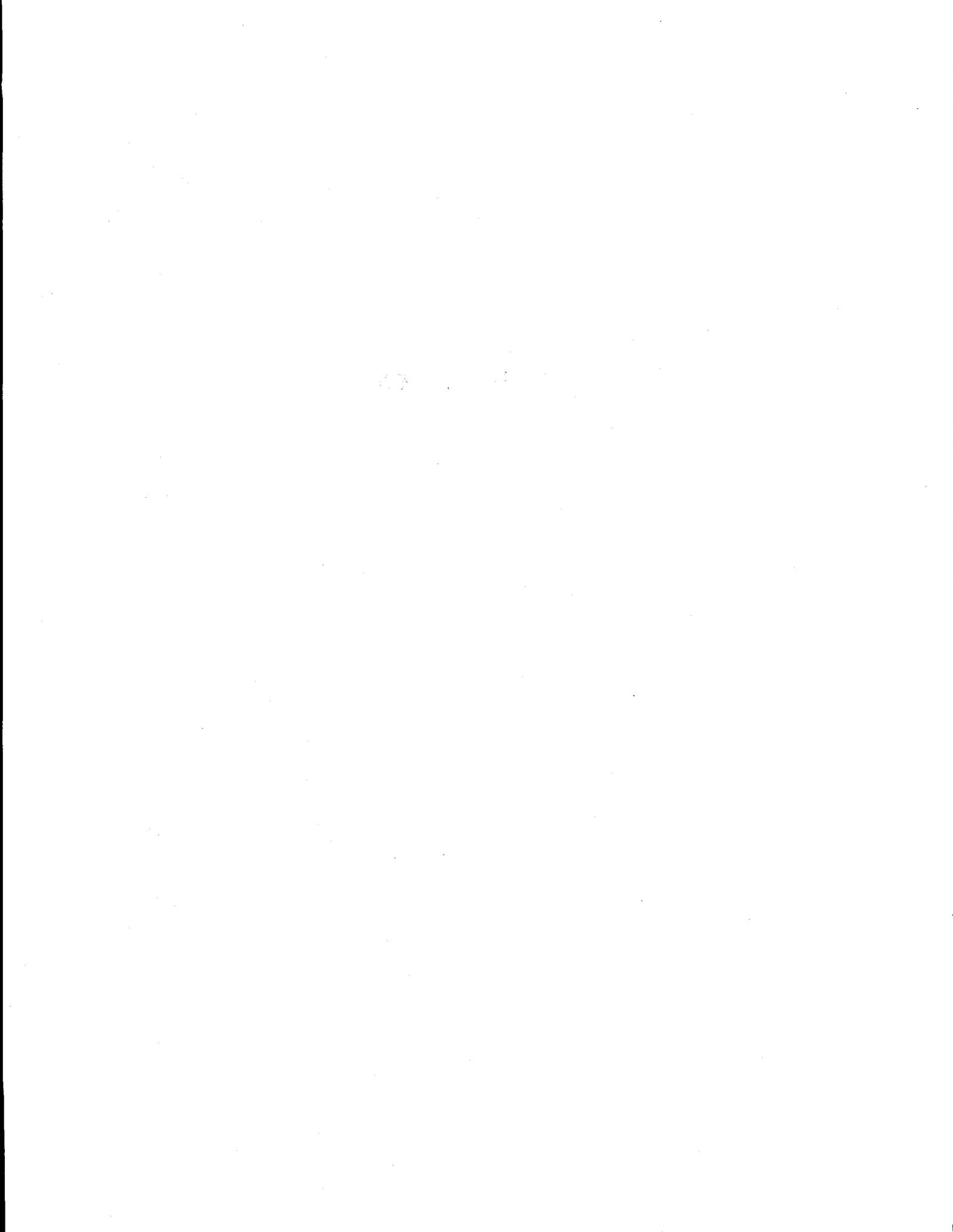
CDIAC produces and distributes newsletters specific to global change interests. CDIAC maintains a small inventory of back issues primarily for archival purposes. Back issues are available as the supply lasts. New subscriptions to these periodicals can be made by indicating your choice on the order form in this catalog.

CDIAC Communications describes the activities, services, information products, and publications of CDIAC and those related to the DOE GCRP. The first public announcements of CDIAC's NDPs, CMPs, and other publications is made in this newsletter. Each issue includes an update of the DOE-sponsored CHAMMP program. (see Factsheet p. 135).

The *DOE Research Summary* is a four-page description of a single DOE-sponsored research project. These newsletters are written by the principle investigators for research projects in progress or near completion. (see Factsheet p. 135).

ARM Outreach provides an overview and update of services and products of the ARM Program. (see Factsheet p. 135).

Author Index



Page		
30	The Impact of Climate Change from Increased Atmospheric Carbon Dioxide on American Agriculture	Achutuni, R.
41	The Use of Statistical Climate-Crop Models for Simulating Yield to Project the Impacts of CO ₂ Induced Climate Change	
116	A Computer-Based Atlas of Global Instrumental Climate Data	Ahern, L. G.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Allen, J. R.
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	Allen, L. H., Jr.
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	Allen, S. G.
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982-1993	Allison, C. E.
14	Carbon in Live Vegetation of Major World Ecosystems	Allison, L. J.
76	Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region	
91	Major World Ecosystem Complexes Ranked by Carbon in Live Vegetation: A Database	
115	The ALE/GAGE/AGAGE Network	Alyea, F.
131	CO ₂ Symposium	American Geophysical Union
69	Intercomparison of Radiation Codes in Climate Models	
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	Anderson, M. G.
121	Global and Latitudinal Estimates of $\delta^{13}\text{C}$ from Fossil-Fuel Consumption and Cement Manufacture	Andres, R. J.
97	Global, Regional, and National Annual CO ₂ Emission Estimates from Fossil Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950-1992	

Author Index

Page

- 89 Annual and Seasonal Global Temperature Anomalies in the Troposphere and Low Stratosphere, 1958–1992 Angell, J. K.
- 94 Annual and Seasonal Global Variation in Total Ozone and Layer—Mean Ozone, 1958–1989
- 101 Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations Apasova, E. G.
- 107 Six- and Three-Hourly Meteorological Observations from 223 U.S.S.R. Stations
- 45 Modeling pCO₂ in the Upper Ocean: A Review of Relevant Physical, Chemical, and Biological Processes Archer, D.
- 115 ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes Arking, A.
- 42 A Preliminary Analysis of U.S. CO₂ Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010 Ashton, W. B.
- 55 Atmospheric Radiation Measurement Program Plan Atmospheric and Climate Research Division, U.S. DOE
- 55 Atmospheric Radiation Measurement Program Plan Executive Summary
- 64 Building an Advanced Climate Model (Program plan for the CHAMMP Climate Modeling Program)
- 56 Identification, Recommendation, and Justification of Potential Locales for ARM Sites
- 55 Identification, Recommendation, and Justification of Potential Locales for ARM Sites, Executive Summary
- 109 Total Carbon Dioxide, Hydrographic, and Nitrate Measurements in the Southwest Pacific During Austral Autumn, 1990: Results from NOAA/PMEL CGC-90 Cruise Atwood, D. K.
- 23 A Two Dimensional CO₂-Ocean Model Including the Biological Processes Baes, C. F., Jr.
- 44 Effects of Air Temperature on Atmospheric CO₂-Plant Growth Relationships Baker, J. T.
- 116 Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data Baldwin, R. G.

Page		
18	Historical Carbon Dioxide: Abundances Derived from the Smithsonian Spectrobolograms	Barnard, J. C.
31	High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air	Barnes, I. L.
43	An Evaluation of the Relationship between the Production and Use of Energy and Atmospheric Methane Emissions	Barns, D. W.
13	On Possible Changes in Global Sea Level and Their Potential Causes	Barnett, T. P.
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature	Barshaw, D.
24	The Effect of Elevated Atmospheric CO ₂ on Plant Communities	Bazzaz, F. A.
89	Atmospheric CO ₂ Concentrations—The CSIRO (Australia) Monitoring Program from Aircraft for 1972-1981	Beardsmore, D. J.
29	Effects of Energy Technology on Global CO ₂ Emissions	Beller, M.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Bhattacharya, N. C.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Bingham, G. E.
99	Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones	Birdwell, K. R.
121	Global and Latitudinal Estimates of $\delta^{13}\text{C}$ from Fossil-Fuel Consumption and Cement Manufacture	Bischof, S.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Biswas, P. K.
117	FORAST Database	Blasing, T. J.
16	Response of the North American Corn Belt to Climate Warming	
87	Tree Ring Chronology Indexes and Reconstructions of Precipitation in Central Iowa, USA	
80	CDIAC Catalog—Numeric Data Packages and Computer Model Packages	Boden, T. A.

Author Index

Page

- 111 CDIAC's Numeric Data Package Collection: Selected Data Sets Relevant to Studies of Greenhouse Gases and Climate (CD-ROM) Boden, T. A. (continued)
- 97 Global, Regional, and National Annual CO₂ Emission Estimates from Fossil Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950–1992
- 81 Trends '93: A Compendium of Data on Global Change
- 73 Bibliography on Tropical Rain Forests and the Global Carbon Cycle Vol. I. An Introduction to the Literature Bogdonoff, P. B.
- 125 Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981 Boote, K. J.
- 47 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report I—Background and Baselines Bowes, M. D.
- 48 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report III—Forest Resources
- 49 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report VI—Consequences of Climate Change for the MINK Economy: Impacts and Responses
- 92 United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data Bowman, D. P.
- 21 A Climatic Data Bank for Northern Hemisphere Land Areas, 1851–1980 Bradley, R. S.
- 46 A Comprehensive Precipitation Data Set for Global Land Areas
- 116 A Computer-Based Atlas of Global Instrumental Climate Data
- 24 A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere
- 92 An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990
- 105 Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V *Meteor* Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE sections A-12 and A-21) Breger, D.

Page		
34	Uncertainty in Future Global Energy Use and Fossil Fuel CO ₂ Emissions 1975 to 2075	Brenkert, A.
87	Transient Tracers in the Oceans (TTO)—Hydrographic Data and Carbon Dioxide Systems With Revised Carbon Chemistry Data	Brewer, P. G.
35	Monthly Mean Pressure Reconstructions for Europe (Back to 1780) and North America (To 1858)	Briffa, K. R.
94	Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980)	
22	Carbon Dynamics of Northern Hardwood Forests: Gas Exchange Characteristics	Briggs, G. M.
23	Reconstruction of Past Atmospheric CO ₂ Contents from the Chemistry of the Contemporary Ocean: An Evaluation	Broecker, W. S.
97	Atmospheric CO ₂ Concentrations Derived from Flask Samples Collected at U.S.S.R-Operated Sampling Sites	Brounshtein, A. M.
102	United States Historical Climatology Network Daily Temperature and Precipitation Data	Brower, W. A.
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature	Brown, S.
116	Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data	Burgin, M. G.
79	Selected Translated Abstracts of Russian-Language Climate-Change Publications. I. Surface Energy Budget	Burtis, M. D.
80	Selected Translated Abstracts of Russian-Language Climate-Change Publications. II. Clouds	
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Campbell, W. J.
76	Catalog of Databases and Reports	Carbon Dioxide Information Analysis Center
77	Glossary: Carbon Dioxide and Climate	
135	Newsletters	
3	The Carbon Dioxide Research Plan: A Summary	Carbon Dioxide Research Division, U.S. DOE
4	Carbon Dioxide and Climate: Summaries of Research in FY 1983 and FY 1984	

Author Index

Page		
4	Carbon Dioxide and Climate: Summaries of Research in FY 1985	Carbon Dioxide Research Division, U.S. DOE (continued)
4	Carbon Dioxide and Climate: Summaries of Research in FY 1986	
4	Carbon Dioxide and Climate: Summaries of Research in FY 1987	
5	Carbon Dioxide and Climate: Summaries of Research in FY 1988	
5	Carbon Dioxide and Climate: Summaries of Research in FY 1989	
5	Carbon Dioxide and Climate: Summaries of Research in FY 1990	Carbon Dioxide Research Program U.S. DOE
5	Carbon Dioxide and Climate: Summaries of Research in FY 1991	
134	The Global Carbon Cycle	
78	Climate Change and Water Supply, Management and Use: Literature Review	Chang, L. H.
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Charlson, R. J.
25	Carbonate Chemistry of the Bering Sea	Chen, C.-T. A.
33, 96	Carbonate Chemistry of the North Pacific Ocean	
16, 96	Carbonate Chemistry of the Weddell Sea	
28	Preliminary Data Report for the INDIVAT Number 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean	
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Chen, J.
41	Documentation of IAP Two-Level Atmospheric General Circulation Model	Chen, S.-F.
29	Effects of Energy Technology on Global CO ₂ Emissions	Cheng, H. C.
20	A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S.	
42	A Preliminary Analysis of U.S. CO ₂ Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010	

Page		
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	Cherry, B. S. G.
26	A Grid-Point Surface Air Temperature Data Set for Southern Hemisphere	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	
133	Atlas of Simultaneous Occurrence of Different Cloud Types Over Land	Chervin, R. M.
132	Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	
94	Climatological Data for Clouds Over the Globe from Surface Observations	
62	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	
64	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	
110	Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Chipman, D. W.
105	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE sections A-12 and A-21)	
66	Review of Carbon Dioxide Research Staffing and Academic Support	Clark, S. B.
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Clough, T.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Coleman, K. B.
88	Atmospheric CO ₂ Concentrations—The NOAA/GMCC Flask and Continuous Sampling Network	Conway, T. J.
115	The ALE/GAGE/AGAGE Network	Crawford, A.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. An Overview	Crosson, P. R.

Author Index

Page

- 47 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report I—Background and Baselines Crosson, P. R.
(continued)
- 47 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IIA—Agricultural Production and Resource Use in the MINK Region Without and With Climate Change
- 49 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report VI—Consequences of Climate Change for the MINK Economy: Impacts and Responses
- 115 The ALE/GAGE/AGAGE Network Cunnold, D.
- 61 Direct Effects of Increasing Carbon Dioxide on Vegetation Cure, J. D.
- 82 Direct Effects of Atmospheric CO₂ Enrichment on Plants and Ecosystems: An Updated Bibliographic Data Base
- 125 Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980
- 78 Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas Cushman, R. M.
- 76 Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region
- 75 Environmental Consequences of CO₂-Climate Interactions: The Need for Integrated Resource Analysis
- 65 Graduate Student Theses Supported by DOE's Environmental Sciences Division
- 130 Workshop on Sea Level Rise and Coastal Processes
- 3 Carbon Cycle Research Plan Dahlman, R. C.
- 3 Vegetation Response to Carbon Dioxide Research Plan
- 78 Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas Daniels, R. C.
- 99 Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones

Page		
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report I—Background and Baselines	Darmstadter, J.
49	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report V—Energy	
30	The Impact of Climate Change from Increased Atmospheric Carbon Dioxide on American Agriculture	Decker, W. L.
41	The Use of Statistical Climate-Crop Models for Simulating Yield to Project the Impacts of CO ₂ Induced Climate Change	
21	A Climatic Data Bank for Northern Hemisphere Land Areas, 1851–1980	Diaz, H. F.
46	A Comprehensive Precipitation Data Set for Global Land Areas	
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	
49	The Determination of Total Dissolved Inorganic Carbon in Sea Water Using Extraction/Coulometry: The First Stage of a Collaborative Study	Dickson, A. G.
82	Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water	
118	Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global Cooperative Air Sampling Network, 1983–1993	Dlugokencky, E. J.
117	FORAST Database	Downing, D. J.
117	FORAST Database	Doyle, T. W.
65	Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) Pilot Project Final Report	Drake, J.
78	Climate Change and Water Supply, Management and Use: Literature Review	Draves, J. D.
76	Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region	

Author Index

Page

- 117 FORAST Database Duvick, D. N.
- 87 Tree Ring Chronology Indexes and Reconstructions of Precipitation in Central Iowa, USA
- 129 Workshop on Oceanic CO₂ Standardization Dyrssen, D.
- 92 United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data Easterling, D. R.
- 116 Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data Easterling, W. E. III
- 47 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report I—Background and Baselines
- 48 Processes for Identifying Regional Influences of and Response to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IIB—A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region
- 125 Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985 Eatman, J. F.
- 131 A Report from the Second U.S./Japan Workshop on Global Change Research: Environmental Response Technologies (Mitigation and Adaptation) Edgerton, S.
- 19 An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO₂ Edmonds, J. A.
- 43 An Evaluation of the Relationship between the Production and Use of Energy and Atmospheric Methane Emissions
- 110 The IEA/ORAU Long-Term Global Energy CO₂ Model
- 111 The IEA/ORAU Long-Term Global Energy CO₂ Model: Personal Computer Version A84PC
- 42 A Preliminary Analysis of U.S. CO₂ Emissions Reduction Potential Conservation and the Substitution of Natural Gas for Coal in the Period to 2010
- 37 A Primer on Greenhouse Gases
- 34 Uncertainty in Future Global Energy Use and Fossil Fuel CO₂ Emissions 1975 to 2075

Page		
46	A Comprehensive Precipitation Data Set for Global Land Areas	Eischeid, J. K.
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	
31	High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air	Elkins, J. W.
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	Ells, J. M.
17	Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Emanuel, W. R.
91	Worldwide Organic Soil Carbon and Nitrogen Data	
119	Intergovernmental Panel on Climate Change (IPCC), Working Group 1, 1994: Modelling Results Relating Future Atmospheric CO ₂ Concentrations to Industrial Emissions	Enting, I. G.
7	Atmospheric Chemistry Program—Program Operation Plan	Environmental Sciences Division, U.S. DOE
7	Atmospheric Sciences Program Summaries of Research in FY 1992	
8	Atmospheric Sciences Program Summaries of Research in FY 1993	
8	Atmospheric Sciences Program. Summaries of Research in FY 1994	
9	Elements of Change 1994. Climate-Radiation Feedbacks: The Current State of the Science	
6	Global Change Research: Summaries of Research in FY 1992	
8	Global Change Research: Summaries of Research in FY 1993	
8	Global Change Research: Summaries of Research in FY 1994	
5	Multi-Year Strategic Plan for the Atmospheric Studies in Complex Terrain (ASCOT) Program	
7	Overview of the DOE Atmospheric Chemistry Program's Ozone Project	

Author Index

Page		
56	The Possible Direct Use of Satellite Radiance Measurements by the Atmospheric Radiation Measurement Program	Environmental Sciences Division, U.S. DOE (continued)
57	Proceedings of the Second Atmospheric Radiation Measurement (ARM) Science Team Meeting	
57	Proceedings of the Third Atmospheric Radiation Measurement (ARM) Science Team Meeting	
57	Proceedings of the Fourth Atmospheric Radiation Measurement (ARM) Science Team Meeting	
57	Science Plan for the Atmospheric Radiation Measurement Program (ARM)	
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982–1993	Enting, I. G.
97	Atmospheric CO ₂ Concentrations Derived from Flask Samples Collected at U.S.S.R.-Operated Sampling Sites	Faber, E. V.
75	Environmental Consequences of CO ₂ -Climate Interactions: The Need for Integrated Resource Analysis	Farrell, M. P.
62	Master Index for the Carbon Dioxide Research State-of-the-Art Report Series	
33, 96	Carbonate Chemistry of the North Pacific Ocean	Feely, R. A.
109	Total Carbon Dioxide, Hydrographic, and Nitrate Measurements in the Southwest Pacific During Austral Autumn, 1990: Results from NOAA/PMEL CGC-90 Cruise	
106	Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986–1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans	
74	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. 2. South Asia	Flint, E. P.
105	Historic Land Use and Carbon Estimates for South and Southeast Asia: 1880–1980	
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Fomin, B.
65	Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) Pilot Project Final Report	Foster, I.

Page		
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982–1993	Francey, R. J.
115	The ALE/GAGE/AGAGE Network	Fraser, P.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report I—Background and Baselines	Frederick, K. D.
48	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IV—Water Resources	
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Freidenreich, S.
50	Climate Data Bases of the People's Republic of China 1841–1988	Fu, C.
101	Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China	
117	Goddard Institute for Space Studies (GISS) 3-Dimensional (3-D) Global Tracer Transport Model	Fung, I.
106	Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986–1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans	Gammon, R. H.
24	The Effect of Elevated Atmospheric CO ₂ on Plant Communities	Garbutt, K.
25	Methods of Uncertainty Analysis for a Global Carbon Dioxide Model	Gardner, R. H.
34	Uncertainty in Future Global Energy Use and Fossil Fuel CO ₂ Emissions 1975 to 2075	
22	Carbon Dynamics of Northern Hardwood Forests: Gas Exchange Characteristics	Gates, D. M.
33, 96	Carbonate Chemistry of the North Pacific Ocean	Gendron, J. F.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Ghosh, P. P.
116	Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Goddard, G.

Author Index

Page		
21	A Climatic Data Bank for Northern Hemisphere Land Areas, 1851–1980	Goodess, C. M.
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	
26	A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1984	
78	Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas	Gornitz, V. M.
103	A Coastal Hazards Data Base for the U.S. East Coast	
103	A Coastal Hazards Data Base for the U.S. Gulf Coast	
110	Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Goyet, C.
109	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991)	
82	Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water	
28	Preliminary Data Report for the INDIVAT Number 1 and INDIGO 1/ INDIVAT 3 Cruises in the Indian Ocean	
100	Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises	Grall, C.
27	Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Grosse, D. J.
38	Regional Intercomparisons of General Circulation Model Predictions and Historical Climate Data	Grotch, S. L.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Guinn, G.
44	Simulating Climate with Two Different Numerical Schemes	Gutowski, W. J.
39	Surface Energy Balance of Three General Circulation Models: Current Climate and Response to Increasing Atmospheric CO ₂	

Page		
39	Surface Energy Balance of Three General Circulation Models: Current Climate and Response to Increasing Atmospheric CO ₂	Gutzler, D. S.
108	Continental Scale Estimates of the Biotic Carbon Flux from Land Cover Change: 1850 to 1980	Hackler, J. L.
133	Atlas of Simultaneous Occurrence of Different Cloud Types Over Land	Hahn, C. J.
132	Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	
94	Climatological Data for Clouds Over the Globe from Surface Observations	
95	Climatological Data for Clouds Over the Globe from Surface Observations, 1982–1991: The Total Cloud Edition	
95	Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1982–1991	
62	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	
64	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Hales, J. M.
31	A Comparison of Tropical Forest Surveys	Hall, C. A. S.
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature	
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Harley, P. C.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Harris, S. M.
43	Global Lake-Level Variations from 18,000 to 0 Years Ago: A Palaeoclimatic Analysis	Harrison, S. P.
34	An Annotated Inventory of Climatic Indices and Data Sets	Hattemer-Frey, H. A.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Heagle, A. S.

Author Index

Page		
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Heck, W. W.
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Heim, R.
119	Intergovernmental Panel on Climate Change (IPCC), Working Group 1, 1994: Modelling Results Relating Future Atmospheric CO ₂ Concentrations to Industrial Emissions	Heimann, M.
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Hilbert, D. W.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Hobbie, J. E.
20	A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S.	Horn, F.
131	Proceedings of the International Symposium on Ecological Aspects of Tree Ring Analysis	Hornbeck, J. W.
108	Continental Scale Estimates of the Biotic Carbon Flux from Land Cover Change: 1850 to 1980	Houghton, R. A.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	
66	Review of Carbon Dioxide Research Staffing and Academic Support	Howard, L.
91	Solar Records: The Wolf Sunspot Index and Umbral/Penumbral Ratio	Hoyt, D. V.
99	Atmospheric CO ₂ Concentrations—The Canadian Background Air Pollution Monitoring Network	Hudec, V. C.
31	High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air	Hughes, E. E.
116	Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data	Hughes, P. Y.
102	United States Historical Climatology Network Daily Temperature and Precipitation Data	
92	United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data	

Page		
78	Climate Change and Water Supply, Management and Use: Literature Review	Hunsaker, C. T.
76	Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region	
44	Simulating Climate with Two Different Numerical Schemes	Iacono, M. J.
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	Idso, S. B.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Israel, D. W.
117	FORAST Database	Jackson, B. L.
131	Proceedings of the International Symposium on Ecological Aspects of Tree Ring Analysis	Jacoby, G. C.
77	Documentation and Analysis of a Global CO ₂ Model Developed by Peng et al.	Jager, H. I.
133	Atlas of Simultaneous Occurrence of Different Cloud Types Over Land	Jenne, R. L.
132	Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	
94	Climatological Data for Clouds Over the Globe from Surface Observations	
62	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	
64	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	
63	Antarctic Surges—A Clear and Present Danger?	Jenssen, D.
109	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991)	Johnson, K. M.
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Jones, J. W.

Author Index

Page		
97	Antarctic Surface Temperature and Pressure Data	Jones, P. D.
21	A Climatic Data Bank for Northern Hemisphere Land Areas, 1851–1980	
46	A Comprehensive Precipitation Data Set for Global Land Areas	
36	Data Bank of Antarctic Surface Temperature and Pressure Data	
93	Global and Hemispheric Annual Temperature Variations Between 1861 and 1991	
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	
26	A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere	
35	Monthly Mean Pressure Reconstructions for Europe (back to 1780) and North America (to 1858)	
94	Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980)	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Jones, P. H.
30	The Impact of Climate Change from Increased Atmospheric Carbon Dioxide on American Agriculture	Jones, V. K.
22	Carbon Dynamics of Northern Hardwood Forests: Gas Exchange Characteristics	Jurik, T. W.
50	Climate Data Bases of the People's Republic of China 1841–1988	Kaiser, D.
81	Trends '93: A Compendium of Data on Global Change	
116	Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data	Karl, T. R.
34	An Annotated Inventory of Climatic Indices and Data Sets	
130	Asymmetric Change of Daily Temperature Range	
50	Climate Data Bases of the People's Republic of China 1841–1988	

Page		
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Karl, T. R. (continued)
93	Historical Sunshine and Cloud Data in the United States	
102	United States Historical Climatology Network Daily Temperature and Precipitation Data	
92	United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data	
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report I—Background and Baselines	Katz, L. A.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IIA—Agricultural Production and Resource Use in the MINK Region Without and With Climate Change	
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. <i>An Introduction to the Literature</i>	Kaufman, E.
87	Atmospheric CO ₂ Concentrations—Mauna Loa Observatory, Hawaii, 1958–1994	Keeling, C. D.
116	A Computer-Based Atlas of Global Instrumental Climate Data	Keimig, F. T.
106	Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986–1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans	Kelly, K. C.
21	A Climatic Data Bank for Northern Hemisphere Land Areas, 1851–1980	Kelly, P. M.
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Kemp, P. R.
118	Atmospheric Methane at Cape Meares, Oregon, U.S.A.: A High-Resolution Data Base for the Period 1979–1992	Khalil, M. A. K.
120	Globally Averaged Atmospheric CFC-11 Concentrations: Monthly and Annual Data for the Period 1975–1992	

Author Index

Page		
17	Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Killough, G. G.
23	A Two Dimensional CO ₂ -Ocean Model Including the Biological Processes	
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Kimball, B. A.
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	
77	Documentation and Analysis of a Global CO ₂ Model Developed by Peng et al.	King, A. W.
75	A Plan for Intermodel Comparison of Atmospheric CO ₂ Projections with Uncertainty Analysis	
116	Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data	Knight, R. W.
89	Annual and Seasonal Global Temperature Anomalies in the Troposphere and Low Stratosphere, 1958-1992	Korshover, J.
94	Annual and Seasonal Global Variation in Total Ozone and Layer-Mean Ozone, 1958-1989	
130	Asymmetric Change of Daily Temperature Range	Kukla, G.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Lakatos, E. A.
90	Volcanic Loading: The Dust Veil Index	Lamb, H. H.
109	Total Carbon Dioxide, Hydrographic, and Nitrate Measurements in the Southwest Pacific During Austral Autumn, 1990: Results from NOAA/PMEL CGC-90 Cruise	Lamb, M. F.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	LaMorte, R. L.
118	Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global Cooperative Air Sampling Network, 1983-1993	Lang, P. M.
109	Rattlesnake Mountain Observatory (46.4° N, 119.6° W) Multispectral Optical Depth Measurements: 1979-1994	Larson, N. R.
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Laulainen, N.

Page		
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Leadley, P. W.
109	Rattlesnake Mountain Observatory (46.4° N, 119.6° W) Multispectral Optical Depth Measurements: 1979–1994	LeBaron, B. A.
78	Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas	Lee, S.-C.
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Leifer, R.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. Report I—Background and Baselines	Lemon, K. M.
48	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. Report IIB—A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region	
41	Documentation of IAP Two-Level Atmospheric General Circulation Model	Liang, X.-Z.
44	Simulating Climate with Two Different Numerical Schemes	
97	Antarctic Surface Temperature and Pressure Data	Limbert, D. W. S.
36	A Data Bank of Antarctic Surface Temperature and Pressure Data	
133	Atlas of Simultaneous Occurrence of Different Cloud Types Over Land	London, J.
132	Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	
94	Climatological Data for Clouds Over the Globe from Surface Observations	
95	Climatological Data for Clouds Over the Globe from Surface Observations, 1982–1991: The Total Cloud Edition	
95	Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1982–1991	
62	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	
64	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	

Author Index

Page		
18	Seasonal Climate Scenarios for Europe and North America in a High-CO ₂ , Warmer World	Lough, J. M.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Lu, J. Y.
134	Natural Sinks of CO ₂	Lugo, A. E.
61	Detecting the Climatic Effects of Increasing Carbon Dioxide	Luther, F. M.
61	Projecting the Climatic Effects of Increasing Carbon Dioxide	
20	A Proposed Reference Set of Scenarios for Radiatively Active Atmospheric Constituents	
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	Luxmoore, R. J.
61	Detecting the Climatic Effects of Increasing Carbon Dioxide	MacCracken, M. C.
61	Projecting the Climatic Effects of Increasing Carbon Dioxide	
20	A Proposed Reference Set of Scenarios for Radiatively Active Atmospheric Constituents	
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	MacDonald, R.
117	FORAST Database	Mann, L. K.
132	Global Climate Feedbacks: Proceedings of the Brookhaven National Laboratory Workshop	Manowitz, B.
43	Global Lake-Level Variations from 18,000 to 0 Years Ago: A Palaeoclimatic Analysis	Marchand, D. S.
14	Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1981	Marland, G.
19	The Changing Pattern of Fossil Fuel CO ₂ Emissions	
121	Global and Latitudinal Estimates of $\delta^{13}\text{C}$ from Fossil-Fuel Consumption and Cement Manufacture	
97	Global, Regional, and National Annual CO ₂ Emission Estimates from Fossil Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950–1992	

Page		
88	Production of CO ₂ from Fossil Fuel Burning by Fuel Type, 1860–1982	Marland, G. (continued)
36	The Prospect of Solving the CO ₂ Problem Through Global Reforestation	
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Martinez, J.
101	Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations	Martuganov, R. A.
107	Six- and Three-hourly Meteorological Observations from 223 U.S.S.R. Stations	
120	Atmospheric Carbon Monoxide Mixing Ratios NOAA Climate Monitoring and Diagnostics Laboratory Cooperative Air Sampling Network, 1988–1993	Masarie, K. A.
118	Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global Cooperative Air Sampling Network, 1983–1993	
102	United States Historical Climatology Network Daily Temperature and Precipitation Data	Mason, E. H.
92	United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data	
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Mauney, J. R.
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Mbikayi, N.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	McCrimmon, J. N.
63	Antarctic Surges—A Clear and Present Danger?	McInnes, B.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. Report I—Background and Baselines	McKenney, M. S.
48	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. Report IIB—A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region	

Author Index

Page		
117	FORAST Database	McLaughlin, S. B.
78	Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas	Mehta, A. J.
130	Workshop on Sea Level Rise and Coastal Processes	
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Melillo, J. M.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Menefee, A.
109	Rattlesnake Mountain Observatory (46.4° N, 119.6° W) Multispectral Optical Depth Measurements: 1979-1994	Michalsky, J. J.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Michell, S. T.
73	Graduate Student Theses Supported by Carbon Dioxide Research Division Office of Basic Energy Sciences, U.S. Department of Energy	Millemann, R. E.
115	The ALE/GAGE/AGAGE Network	Miller, B.
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Mishoe, J. W.
131	A Report from the Second U.S./Japan Workshop on Global Change Research: Environmental Response Technologies (Mitigation and Adaptation)	Mizuno, T.
31	A Comparison of Tropical Forest Surveys	Molofsky, J.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Moore, B.
109	Total Carbon Dioxide, Hydrographic, and Nitrate Measurements in the Southwest Pacific During Austral Autumn, 1990: Results from NOAA/PMEL CGC-90 Cruise	Moore, L.
106	Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986-1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans	Murphy, P. P.
31	A Comparison of Tropical Forest Surveys	Myers, N.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Nakayama, F. S.

Author Index

Page		
81	Report of the International Workshop on Quality Control of Monthly Climate Data	National Climatic Data Center
129	Flux of Organic Carbon by Rivers to the Oceans	National Research Council
111	CDIAC's Numeric Data Package Collection: Selected Data Sets Relevant to Studies of Greenhouse Gases and Climate (CD-ROM)	Nelson, T. R.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Nixon, P. E. III
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	Norby, R. J.
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Novakov, T.
120	Atmospheric Carbon Monoxide Mixing Ratios NOAA Climate Monitoring and Diagnostics Laboratory Cooperative Air Sampling Network, 1988–1993	Novelli, P. C.
51	Photosynthesis, Environmental Change, and Plant Adaptation—Research Topics in Plant Molecular Ecology	Office of Basic Energy Sciences, U.S. DOE
9	Natural and Accelerated Bioremediation Research (NABIR)	Office of Energy Research, U.S. DOE
68	Global Climate Trends and Greenhouse Gas Data: Federal Activities in Data Collection, Archiving, and Dissemination. Report to the Congress of the United States	Office of Environmental Analysis, U.S. DOE
51	Photosynthesis, Environmental Change, and Plant Adaptation—Research Topics in Plant Molecular Ecology	Office of Health and Environmental Research, U.S. DOE
129	Workshop on Environmental and Societal Consequences of a Possible CO ₂ -Induced Climate Change	
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Ogren, J.
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature	O'Hara, F. M. Jr.
80	CDIAC Catalog—Numeric Data Packages and Computer Model Packages	

Author Index

Page		
33, 96	Carbonate Chemistry of the North Pacific Ocean	Olson, E. J.
14	Carbon in Live Vegetation of Major World Ecosystems	Olson, J. S.
91	Major World Ecosystem Complexes Ranked by Carbon in Live Vegetation: A Database	
91	Worldwide Organic Soil Carbon and Nitrogen Data	
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	O'Neill, E. G.
96	GEOSECS Atlantic, Pacific, Indian, and Mediterranean Radiocarbon Data	Östlund, H. G.
100	Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises	
129	Workshop on Oceanic CO ₂ Standardization	
27	Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Ostrander, G. K.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	Pace, R. D.
117	FORAST Database	Pack, J. D.
18	Seasonal Climate Scenarios for Europe and North America in a High-CO ₂ , Warmer World	Palutikof, J. P.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Park, A. B.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Parker, L. L.
65	Graduate Student Theses Supported by DOE's Environmental Sciences Division	Parra, B. M.
89	Atmospheric CO ₂ Concentrations—The CSIRO (Australia) Monitoring Program From Aircraft for 1972–1981	Pearman, G. I.
18	Historical Carbon Dioxide: Abundances Derived from the Smithsonian Spectrograms	Pearson, E. W.

Page		
77	Documentation and Analysis of a Global CO ₂ Model Developed by Peng et al.	Peng, T.-H.
23	Reconstruction of Past Atmospheric CO ₂ Contents from the Chemistry of the Contemporary Ocean: An Evaluation	
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Penner, J. E.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Peresta, G. J.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Peterson, B. J.
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Peterson, T. C.
94	Annual and Seasonal Global Variation in Total Ozone and Layer-Mean Ozone, 1958-1989	Planet, W. G.
28	Preliminary Data Report for the INDIVAT Number 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean	Poisson, A.
66	Glaciers, Ice Sheets, and Sea Level: National Res. Council Effect of a CO ₂ -Induced Climatic Change	Polar Research Board
39	Surface Energy Balance of Three General Circulation Models: Current Climate and Response to Increasing Atmospheric CO ₂	Portman, D.
122	Global Patterns of Carbon Dioxide Emissions from Soils on a 0.5 Degree Grid Cell Basis	Potter, C. S.
17	Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Post, W. M.
91	Worldwide Organic Soil Carbon and Nitrogen Data	
25	The Stability of Low-Latitude Sea Surface Temperatures: An Evaluation of the CLIMAP Reconstruction with Emphasis on the Positive SST Anomalies	Prell, W. L.
115	The ALE/GAGE/AGAGE Network	Prinn, R.
121	A Global 1 Degree by 1 Degree Distribution of Atmospheric/Soil CO ₂ Consumption by Continental Weathering and a Riverine HCO ₃ Yield	Probst, J.-L.

Author Index

Page		
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Pros, H.
34	An Annotated Inventory of Climatic Indices and Data Sets	Quinlan, F. T.
100	Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ , Irrigation, and Nitrogen	Radin, J. W.
44	Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Radke, L. F.
63	Antarctic Surges—A Clear and Present Danger?	Radok, U.
122	Global Patterns of Carbon Dioxide Emissions from Soils on a 0.5 Degree Grid Cell Basis	Raich, J. W.
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	Raper, S. C. B.
26	A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	
118	Atmospheric Methane at Cape Meares, Oregon, U.S.A.: A High-Resolution Data Base for the Period 1979–1992	Rasmussen, R. A.
120	Globally Averaged Atmospheric CFC-11 Concentrations: Monthly and Annual Data for the Period 1975–1992	
79	Selected Translated Abstracts of Russian-Language Climate-Change Publications. I. Surface Energy Budget	Ravina, C. B.
80	Selected Translated Abstracts of Russian-Language Climate-Change Publications. II. Clouds	
101	Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations	Razuvaev, V. N.
83	Selected Translated Abstracts of Russian-Language Climate-Change Publications. III. Aerosols	
107	Six- and Three-hourly Meteorological Observations from 223 U.S.S.R. Stations	
19	An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO ₂	Reichle, D. E.

Page		
19	An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO ₂	Reilly, J. M.
110	The IEA/ORAU Long-Term Global Energy-CO ₂ Model	
111	The IEA/ORAU Long-Term Global Energy-CO ₂ Model: Personal Computer Version A84PC	
34	Uncertainty in Future Global Energy Use and Fossil Fuel CO ₂ Emissions 1975 to 2075	
50	Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Reynolds, J. F.
74	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. 2. South Asia	Richards, J. F.
105	Historic Land Use and Carbon Estimates for South and Southeast Asia: 1880–1980	
130	Asymmetric Change of Daily Temperature Range	Riches, M. R.
3	CO ₂ Climate Research Plan	
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Ridgway, B.
43	Global Lake-Level Variations from 18,000 to 0 Years Ago: A Palaeoclimatic Analysis	Roberts, N.
25	Carbonate Chemistry of the Bering Sea	Rodman, M. R.
33, 96	Carbonate Chemistry of the North Pacific	
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Rogers, H. H.
125	Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Carbon Dioxide, 1985	
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	
31	High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air	Rook, H. L.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. An Overview	Rosenberg, N. J.

Author Index

Page

- 47 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report I—Background and Baselines Rosenberg, N. J.
(continued)
- 48 Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO₂ and Climate Change—The MINK Project. Report IIB—A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region
- 14 Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950–1981 Rotty, R. M.
- 19 The Changing Pattern of Fossil Fuel CO₂ Emissions
- 88 Production of CO₂ From Fossil Fuel Burning by Fuel Type, 1860–1982
- 110 Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V *Thomas Washington*, July–August 1991 Rubin, S.
- 104 Surface Water and Atmospheric Carbon Dioxide and Nitrous Oxide Observations by Shipboard Automated Gas Chromatography: Results From Expeditions Between 1977 and 1990 Salameh, P. K.
- 77 Documentation and Analysis of a Global CO₂ Model Developed by Peng et al. Sale, M. J.
- 75 A Plan for Intermodel Comparison of Atmospheric CO₂ Projections with Uncertainty Analysis
- 24 A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere Santer, B.
- 92 An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990
- 100 Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO₂, Irrigation, and Nitrogen Savoy, B.
- 129 Proceedings of the Carbon Dioxide and Climate Research Program Conference Schmitt, L. E.
- 102 The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data Schmoyer, R. L.
- 67 Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols Schwartz, W. E.

Page		
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Schwarzkopf, D.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report I—Background and Baselines	Sedjo, R. A.
48	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report III—Forest Resources	
81	Trends '93: A Compendium of Data on Global Change	Sepanski, R. J.
97	Atmospheric CO ₂ Concentrations Derived from Flask Samples Flask Samples Collected at U.S.S.R-Operated Sampling Sites	Shashkov, A. A.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Shaver, G. R.
17	Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Shugart, H. H.
27	Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Sibley, T. H.
115	The ALE/GAGE/AGAGE Network	Simmonds, P.
83	Selected Translated Abstracts of Russian-Language Climate-Change Publications. III. Aerosols	Sivachok, S. G.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Smith, J. M.
16	Response of the North American Corn Belt to Climate Warming	Solomon, A. M.
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	
91	Worldwide Organic Soil Carbon and Nitrogen Data	Stangenberger, A. G.
118	Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global Cooperative Flask Sampling Network, 1983–1993	Steele, L. P.
16	An Analysis of Concepts for Controlling Atmospheric Carbon Dioxide	Steinberg, M.
29	Effects of Energy Technology on Global CO ₂ Emissions	

Author Index

Page		
42	A Preliminary Analysis of U.S. CO ₂ Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010	Steinberg, M. (continued)
20	A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S.	
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Steurer, P. M.
93	Historical Sunshine and Cloud Data in the United States	
108	Carbon-13 Isotopic Abundance and Concentration of Atmospheric Methane for Background Air in the Southern and Northern Hemispheres from 1978 to 1989	Stevens, C. M.
17	Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Stevenson, M. P.
66	Review of Carbon Dioxide Research Staffing and Academic Support	Stevenson, W.
18	Historical Carbon Dioxide: Abundances Derived from the Smithsonian Spectrobolograms	Stokes, G. M.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Stone, T. A.
80	CDIAC Catalog—Numeric Data Packages and Computer Model Model Packages	Stoss, F. W.
135	CDIAC Fact Sheets	
83	Global Change Acronyms & Abbreviations	
81	Trends '93: A Compendium of Data on Global Change	
61	Direct Effects of Increasing Carbon Dioxide on Vegetation	Strain, B. R.
82	Direct Effects of Atmospheric CO ₂ Enrichment on Plants and Ecosystems: An Updated Bibliographic Data Base	
43	Global Lake-Level Variations from 18,000 to 0 Years Ago: A Palaeoclimatic Analysis	Street-Perrott, F. A.
27	Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Strickland, R. M.

Page		
27	Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Stubin, A. I.
96	GEOSECS Atlantic, Pacific, Indian, and Mediterranean Radiocarbon Data	Stuiver, M.
121	A Global 1 Degree by 1 Degree Distribution of Atmospheric/Soil CO ₂ Consumption by Continental Weathering and a Riverine HCO ₃ Yield	Suchet, P. A.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Surano, K. A.
110	Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Sutherland, S. C.
105	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE sections A-12 and A-21)	
65	Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) Pilot Project Final Report	Swarztrauber, P.
110	Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Takahashi, T.
105	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE sections A-12 and A-21)	
23	Reconstruction of Past Atmospheric CO ₂ Contents from the Chemistry of the Contemporary Ocean: An Evaluation	
87	Transient Tracers in the Oceans (TTO)—Hydrographic Data and Carbon Dioxide Systems With Revised Carbon Chemistry Data	
88	Atmospheric CO ₂ Concentrations—The NOAA/GMCC Flask and Continuous Sampling Network	Tans, P. P.
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982–1993	

Author Index

Page		
50	Climate Data Bases of the People's Republic of China 1841–1988	Tao, S.
101	Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China	
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	Taylor, G. E.
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	Tharp, M. L.
125	Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	Thomas, J. F.
19	An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO ₂	Trabalka, J. R.
62	Atmospheric Carbon Dioxide and the Global Carbon Cycle	
25	Methods of Uncertainty Analysis for a Global Carbon Dioxide Model	
67	Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	Travis, L.
19	The Changing Pattern of Fossil Fuel CO ₂ Emissions	Treat, N.
66	Review of Carbon Dioxide Research Staffing and Academic Support	Trice, J.
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	Trimble, J. L.
99	Atmospheric CO ₂ Concentrations—The Canadian Background Air Pollution Monitoring Network	Trivett, N. B. A.
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982–1993	Trolier, M.
115	ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Trotsenko, A.
73	Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature	Underhill, S.
68	Policy Statements on Data Management for Global Change Research	U.S. Global Change Research Program
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Valle, R.

Page		
104	Surface Water and Atmospheric Carbon Dioxide and Nitrous Oxide Observations by Shipboard Automated Gas Chromatography: Results From Expeditions Between 1977 and 1990	Van Woy, F. A.
102	The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Vose, R. S.
125	Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Vu, C. V.
109	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991)	Wallace, D. W. R.
50	Climate Data Bases of the People's Republic of China 1841–1988	Wang, W.-C.
13	Effects of Approximate Radiation Treatments Used in the Climate Models on the Clear Sky Thermal Radiation Flux and its Perturbation Due to CO ₂ Increase	
44	Simulating Climate with Two Different Numerical Schemes	
39	Surface Energy Balance of Three General Circulation Models: Current Climate and Response to Increasing Atmospheric CO ₂	
133	Atlas of Simultaneous Occurrence of Different Cloud Types Over Land	Warren, S. G.
132	Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	
94	Climatological Data for Clouds Over the Globe from Surface Observations	
95	Climatological Data for Clouds Over the Globe from Surface Observations, 1982–1991: The Total Cloud Edition	
95	Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1982–1991	
62	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	
64	Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	
75	Environmental Consequences of CO ₂ -Climate Interactions: The Need for Integrated Resource Analysis	Waterhouse, J. C.

Author Index

Page		
14	Carbon in Live Vegetation of Major World Ecosystems	Watts, J. A.
91	Major World Ecosystem Complexes Ranked by Carbon in Live Vegetation: A Database	
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	Webb, J. W.
21	A Global Paleoclimatic Data Base for 6000 Year B.P.	Webb, T. III
90	Global Paleoclimatic Data for 6000 Yr. B.P.	
25	Carbonate Chemistry of the Bering Sea	Wei, C.-L.
33, 96	Carbonate Chemistry of the North Pacific Ocean	
115	The ALE/GAGE/AGAGE Network	Weiss, R.
104	Surface Water and Atmospheric Carbon Dioxide and Nitrous Oxide Observations by Shipboard Automated Gas Chromatography: Results From Expeditions Between 1977 and 1990	Weiss, R. F.
89	Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	Weller, D. G.
17	Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	West, D. C.
122	<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania, Australia: 1982–1993	White, J. W. C.
61	Characterization of Information Requirements for Studies of CO ₂ Effects: Water Resources, Agriculture, Fisheries, Forests, and Human Health	White, M. R.
103	A Coastal Hazards Data Base for the U.S. East Coast	White, T. W.
103	A Coastal Hazards Data Base for the U.S. Gulf Coast	
76	Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region	
93	Global and Hemispheric Annual Temperature Variations Between 1861 and 1988	Wigley, T. M. L.
24	A Grid Point Surface Air Temperature Data Set for the Northern Hemisphere	

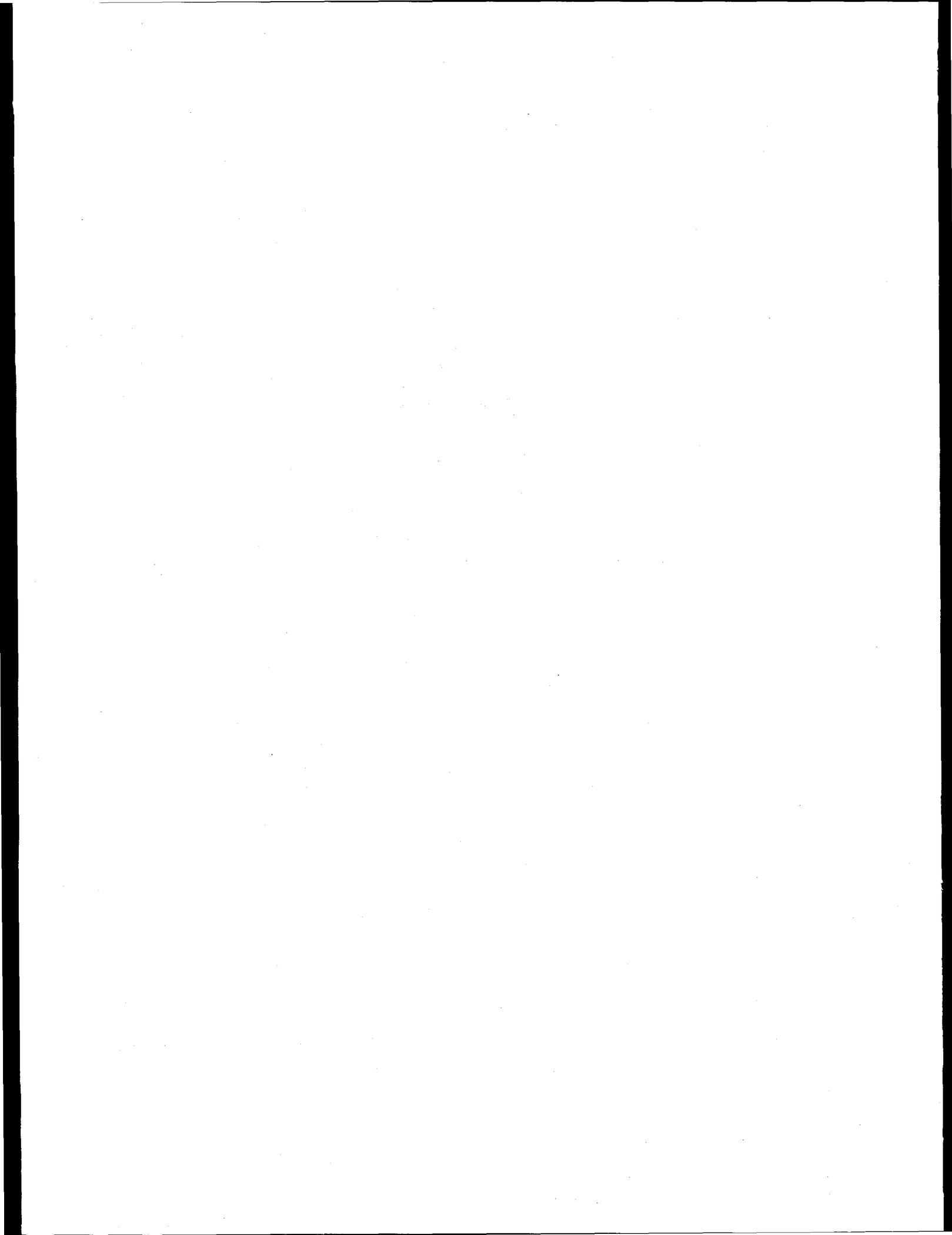
Page		
26	A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere	Wigley, T. M. L. (continued)
119	Intergovernmental Panel on Climate Change (IPCC), Working Group 1, 1994: Modelling Results Relating Future Atmospheric CO ₂ Concentrations to Industrial Emissions	
35	Monthly Mean Pressure Reconstructions for Europe (back to 1780) and North America (to 1858)	
94	Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980)	
18	Seasonal Climate Scenarios for Europe and North America in a High-CO ₂ , Warmer World	
92	An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1984	
109	Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991)	Wilke, R. J.
87	Transient Tracers in the Oceans (TTO)—Hydrographic Data and Carbon Dioxide Systems With Revised Carbon Chemistry Data	Williams, R. T.
24	The Effect of Elevated Atmospheric CO ₂ on Plant Communities	Williams, W. E.
47	Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IIA—Agricultural Production and Resource Use in the MINK Region Without and With Climate Change	Wingard, J.
134	Natural Sinks of CO ₂	Wisniewski, J.
99	Atmospheric CO ₂ Concentrations—The Canadian Background Air Pollution Monitoring Network	Wong, C. S.
83	Global Change Acronyms & Abbreviations	Woodard, C. T.
15	Deforestation Measured by LANDSAT: Steps Toward a Method	Woodwell, G. M.
93	Global and Hemispheric Annual Temperature Variations Between 1861 and 1991	Wright, P. B.
37	A Primer on Greenhouse Gases	Wuebbles, D. J.
20	A Proposed Reference Set of Scenarios for Radiatively Active Atmospheric Constituents	

Author Index

Page

- | | | |
|-----|--|----------------------|
| 41 | Documentation of IAP Two-Level Atmospheric General Circulation Model | Yuan, C.-G. |
| 41 | Documentation of IAP Two-Level Atmospheric General Circulation Model | Zeng, Q.-C. |
| 101 | Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China | Zeng, Z. |
| 50 | Climate Data Bases of the People's Republic of China 1841-1988 | Zhang, Q. |
| 101 | Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China | |
| 41 | Documentation of IAP Two-Level Atmospheric General Circulation Model | Zhang, X.-H. |
| 31 | High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air | Zielinski, W. L. Jr. |
| 91 | Worldwide Organic Soil Carbon and Nitrogen Data | Zinke, P. J. |

Title Index



		Page
<p>Adapting to Sea-Level Rise in the U.S. Southeast: The Influence of Built Infrastructure and Biophysical Factors on the Inundation of Coastal Areas</p>	<p>Daniels, R. C. V. M. Gornitz A. J. Mehta S.-C. Lee R. M. Cushman</p>	<p>78</p>
<p>Alaskan Historical Climatology Network (HCN) Serial Temperature and Precipitation Data</p>	<p>Karl, T. R. R. G. Baldwin M. G. Burgin D. R. Easterling R. W. Knight P. Y. Hughes</p>	<p>116</p>
<p>The ALE/GAGE/AGAGE Network</p>	<p>Prinn, R. D. Cunnold P. Fraser R. Weiss P. Simmonds B. Miller F. Alyea A. Crawford</p>	<p>115</p>
<p>An Analysis of Concepts for Controlling Atmospheric Carbon Dioxide</p>	<p>Steinberg, M.</p>	<p>16</p>
<p>An Analysis of Possible Future Atmospheric Retention of Fossil Fuel CO₂</p>	<p>Edmonds, J. A. J. Reilly J. R. Trabalka D. E. Reichle</p>	<p>19</p>
<p>An Annotated Inventory of Climatic Indices and Data Sets</p>	<p>Hattermer-Frey, H. A. T. R. Karl F. T. Quinlan</p>	<p>34</p>
<p>Annual and Seasonal Global Temperature Anomalies in the Troposphere and Low Stratosphere, 1958–1992</p>	<p>Angell, J. K. J. Korshover</p>	<p>89</p>
<p>Annual and Seasonal Global Variation In Total Ozone and Layer-Mean Ozone, 1958-1989</p>	<p>Angell, J. K. J. Korshover W. G. Planet</p>	<p>94</p>
<p>Antarctic Surface Temperature and Pressure Data</p>	<p>Jones, P. D. D. W. S. Limbert</p>	<p>97</p>
<p>Antarctic Surges—A Clear and Present Danger?</p>	<p>Radok, U. D. Jenssen B. McInnes</p>	<p>63</p>

Title Index

		Page
Asymmetric Change of Daily Temperature Range	Kukla, G. T. R. Karl M. R. Riches	130
Atlas of Simultaneous Occurrence of Different Cloud Type Over Land	Hahn, C. J. S. G. Warren J. London R. M. Chervin R. Jenne	133
Atlas of Simultaneous Occurrence of Different Cloud Types Over the Ocean	Hahn, C. J. S. G. Warren J. London R. M. Chervin R. Jenne	132
Atmospheric Carbon Dioxide and the Global Carbon Cycle	Trabalka, J. R.	62
Atmospheric Carbon Monoxide Mixing Ratios NOAA Climate Monitoring and Diagnostics Laboratory Cooperative Air Sampling Network, 1988-1993	Novelli, P. C. K. A. Masarie	120
Atmospheric Chemistry Program. Program Operation Plan	Environmental Sciences Division, U.S. DOE	7
Atmospheric CO ₂ Concentrations—The Canadian Background Air Pollution Monitoring Network	Trivett, N. B. A. V. C. Hudc C. S. Wong	99
Atmospheric CO ₂ Concentrations—The CSIRO (Australia) Monitoring Program from Aircraft for 1972-1981	Beardsmore, D. J. G. I. Pearman	89
Atmospheric CO ₂ Concentrations Derived from Flask Samples Collected at U.S.S.R.-Operated Sampling Sites	Brounshtein, A. M. E. V. Faber A. A. Shashkov	97
Atmospheric CO ₂ Concentrations—Mauna Loa Observatory, Hawaii, 1958-1994	Keeling, C. D.	87
Atmospheric CO ₂ Concentrations—The NOAA/GMCC Flask and Continuous Sampling Network	Conway, T. J. P. Tans	88
Atmospheric Methane at Cape Meares, Oregon, U.S.A.: A High-Resolution Data Base for the Period 1979-1992	Khalil, M. A. K. R. A. Rasmussen	118

		Page
<p>Atmospheric Methane Mixing Ratios—The NOAA/CMDL Global Cooperative Air Sampling Network, 1983–1993</p>	<p>Dlugokencky, E. J. P. M. Lang K. A. Masarie L. P. Steele</p>	<p>118</p>
<p>Atmospheric Radiation Measurement Program Plan</p>	<p>Atmospheric and Climate Research Division, U.S. DOE</p>	<p>55</p>
<p>Atmospheric Radiation Measurement Program Plan, Executive Summary</p>		<p>55</p>
<p>Atmospheric Sciences Program Summaries of Research in FY 1992</p>	<p>Environmental Sciences Division, U.S. DOE</p>	<p>7</p>
<p>Atmospheric Sciences Program. Summaries of Research in FY 1993</p>		<p>8</p>
<p>Atmospheric Sciences Program. Summaries of Research in FY 1994</p>		<p>8</p>
<p>Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. I. An Introduction to the Literature</p>	<p>Hall, C. A. S. S. Brown F. M. O'Hara, Jr. P. B. Bogdonoff D. Barshaw E. Kaufman S. Underhill</p>	<p>73</p>
<p>Bibliography on Tropical Rain Forests and the Global Carbon Cycle. Vol. 2. South Asia</p>	<p>Flint, E. P. J. F. Richards</p>	<p>74</p>
<p>Building an Advanced Climate Model Program Plan for the CHAMMP Climate Modeling Program</p>	<p>Atmospheric and Climate Research Division, U.S. DOE</p>	<p>64</p>
<p>Carbon-13 Isotopic Abundance and Concentration of Atmospheric Methane for Background Air in the Southern and Northern Hemispheres from 1978 to 1989</p>	<p>Stevens, C. M.</p>	<p>108</p>
<p>Carbon Cycle Research Plan</p>	<p>Dahlman, R. C.</p>	<p>3</p>

Title Index

	Page
Carbon Dioxide and Climate: Summaries of Research in FY 1983 and FY 1984	Carbon Dioxide Research Division, U.S. DOE 4
Carbon Dioxide and Climate: Summaries of Research in FY 1985	4
Carbon Dioxide and Climate: Summaries of Research in FY 1986	4
Carbon Dioxide and Climate: Summaries of Research in FY 1987	4
Carbon Dioxide and Climate: Summaries of Research in FY 1988	5
Carbon Dioxide and Climate: Summaries of Research in FY 1989	Carbon Dioxide Research Program, U.S. DOE 5
Carbon Dioxide and Climate: Summaries of Research in FY 1990	5
Carbon Dioxide and Climate: Summaries of Research in FY 1991	5
Carbon Dioxide Concentrations in Surface Water and the Atmosphere During 1986-1989 NOAA/PMEL Cruises in the Pacific and Indian Oceans	Murphy, P. P. 106 K. C. Kelly R. A. Feely R. H. Gammon
Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950-1981	Marland, G. 14 R. M. Rotty
Carbon Dioxide Enrichment: Data on the Response of Cotton to Varying CO ₂ Irrigation, and Nitrogen	Kimball, B. A. 100 J. R. Mauney R. L. LaMorte G. Guinn F. S. Nakayama J. W. Radin E. A. Lakatos S. T. Mitchell L. L. Parker G. J. Peresta P. E. Nixon III B. Savoy S. M. Harris R. MacDonald H. Pros J. Martinez

		Page
Carbon Dioxide, Hydrographic, and Chemical Data Obtained in the Central South Pacific Ocean (WOCE Sections P17S and P16S) During the TUNES-2 Expedition of the R/V <i>Thomas Washington</i> , July–August 1991	Takahashi, T. G. Goddard S. Rubin D. W. Chipman S. C. Sutherland C. Goyet	110
Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 11/5 in the South Atlantic and Northern Weddell Sea Areas (WOCE sections A-12 and A-21)	Chipman, D. W. T. Takahashi D. Breger S. C. Sutherland	105
Carbon Dioxide, Hydrographic, and Chemical Data Obtained During the R/V <i>Meteor</i> Cruise 15/3 in the South Atlantic Ocean (WOCE Section A9, February–March 1991)	Johnson, K. M. D. W. R. Wallace R. J. Wilke C. Goyet	109
The Carbon Dioxide Research Plan: A Summary	Carbon Dioxide Research Division, U.S. DOE	3
Carbon Dynamics of Northern Hardwood Forests: Gas Exchange Characteristics	Jurik, T. W. G. M. Briggs D. M. Gates	22
Carbon in Live Vegetation of Major World Ecosystems	Olson, J. S. J. A. Watts L. J. Allison	14
Carbonate Chemistry of the Bering Sea	Chen, C.-T. A. C.-L. Wei M. R. Rodman	25
Carbonate Chemistry of the North Pacific Ocean	Chen, C.-T. A. M. R. Rodman C.-L. Wei E. J. Olson R. A. Feely J. F. Gendron	33, 96
Carbonate Chemistry of the Weddell Sea	Chen, C.-T. A.	16, 96
Catalog of Databases and Reports	Carbon Dioxide Information Analysis Center	76
CDIAC Catalog—Numeric Data Packages and Computer Model Packages	Boden, T. A. F. A. O'Hara, Jr. F. W. Stoss	80

Title Index

	Page
CDIAC Fact Sheets	Stoss, F. W. 135
CDIAC's Numeric Data Package Collection: Selected Data Sets Relevant to Studies of Greenhouse Gases and Climate (CD-ROM)	Nelson, T. R. 111 T. A. Boden
The Changing Pattern of Fossil Fuel CO ₂ Emissions	Rotty, R. M. 19 G. Marland N. Treat
Characterization of Information Requirements for Studies of CO ₂ Effects: Water Resources, Agriculture, Fisheries, Forests, and Human Health	White, M. R. 61
Climate Change and Water Supply, Management and Use: Literature Review	Chang, L. H. 78 J. D. Draves C. T. Hunsaker
Climate Data Bases of the People's Republic of China 1841-1988	Kaiser, D. 50 S. Tao C. Fu Q. Zhang W.-C. Wang T. Karl
A Climatic Data Bank for Northern Hemisphere Land Areas, 1851-1980	Bradley, R. S. 21 P. M. Kelly P. D. Jones C. M. Goodess H. F. Diaz
Climatological Data for Clouds Over the Globe from Surface Observations	Hahn, C. J. 94 S. G. Warren J. London R. L. Jenne R. M. Chervin
Climatological Data for Clouds Over the Globe from Surface Observations, 1982-1991: The Total Cloud Edition	Hahn, C. J. 95 S. G. Warren J. London
A Coastal Hazards Data Base for the U.S. East Coast	Gornitz, V. M. 103 T. W. White
A Coastal Hazards Data Base for the U.S. Gulf Coast	Gornitz, V. M. 103 T. W. White

		Page
CO ₂ Climate Research Plan	Riches, M. R.	3
CO ₂ Symposium	American Geophysical Union	131
A Comparison of Tropical Forest Surveys	Molofsky, J. C. A. S. Hall N. Myers	31
A Comprehensive Precipitation Data Set for Global Land Areas	Eischeid, J. K. H. F. Diaz R. S. Bradley P. D. Jones	46
A Computer-Based Atlas of Global Instrumental Climate Data	Bradley, R. S. L. G. Ahern F. T. Keimig	116
Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) Pilot Project Final Report	Drake, J. I. Foster P. Swartrauber	65
Computer Implementation of a Globally Averaged Model of the World Carbon Cycle	Emanuel, W. R. G. G. Killough W. M. Post H. H. Shugart M. P. Stevenson	17
Continental Scale Estimates of the Biotic Carbon Flux from Land Cover Change: 1850 to 1980	Houghton, R. A. J. L. Hackler	108
Daily Temperature and Precipitation Data for 223 U.S.S.R. Stations	Razuvaev, V. N. E. G. Apasova R. A. Martuganov	101
A Data Bank of Antarctic Surface Temperature and Pressure Data	Jones, P. D. D. W. S. Limbert	36
Definition and Characterization of Data Needs to Describe the Potential Effects of Increased Atmospheric CO ₂ on Marine Fisheries from the Northeast Pacific Ocean	Strickland, R. M. D. J. Grosse A. I. Stubin G. K. Ostrander T. H. Sibley	27

Title Index

		Page
Deforestation Measured by LANDSAT: Steps Toward a Method	Woodwell, G. M. J. E. Hobbie R. A. Houghton J. M. Melillo B. J. Peterson G. R. Shaver T. A. Stone B. Moore A. B. Park	15
Detecting the Climatic Effects of Increasing Carbon Dioxide	MacCracken, M. C. F. M. Luther	61
The Determination of Total Dissolved Inorganic Carbon in Sea Water Using Extraction/Coulometry: The First Stage of a Collaborative Study	Dickson, A. G.	49
Direct Effects of Atmospheric CO ₂ Enrichment on Plants and Ecosystems: An Updated Bibliographic Data Base	Strain, B. R. J. D. Cure	82
Direct Effects of Increasing Carbon Dioxide on Vegetation	Strain, B. R. J. D. Cure	61
Documentation and Analysis of a Global CO ₂ Model Developed by Peng et al.	Jager, H. I. T.-H. Peng A. W. King M. J. Sale	77
Documentation of IAP Two-Level Atmospheric General Circulation Model	Zeng, Q.-C. X. H. Zhang X.-Z. Liang C.-G. Yuan S.-F. Chen	41
Edited Synoptic Cloud Reports from Ships and Land Stations Over the Globe, 1982-1991	Hahn, C. J. S. G. Warren J. London	95
The Effect of Elevated Atmospheric CO ₂ on Plant Communities	Bazzaz, F. A. K. Garbutt W. E. Williams	24

		Page
Effects of Air Temperature on Atmospheric CO ₂ -Plant Growth Relationships	Allen, S. G. S. B. Idso B. A. Kimball J. T. Baker L. H. Allen Jr. J. R. Mauney J. W. Radin M. G. Anderson	44
Effects of Approximate Radiation Treatments Used in the Climate Models on the Clear Sky Thermal Radiation Flux and its Perturbation Due to CO ₂ Increase	Wang, W.-C.	13
Effects of Energy Technology on Global CO ₂ Emissions	Cheng, H. C. M. Steinberg M. Beller	29
Effects of Increased Carbon Dioxide on Photosynthesis and Agricultural Productivity of Soybeans, 1981	Allen, L. H. Jr. K. J. Boote J. W. Jones J. W. Mishoe P. H. Jones C. V. Vu R. Valle W. J. Campbell	125
Elements of Change 1994. Climate-Radiation Feedbacks: The Current State of the Science	Environmental Sciences Division, U.S. DOE	9
Environmental Atlas of the Iowa-Kansas-Missouri-Nebraska Climate-Change Study Region	Allison, L. J. C. T. Hunsaker R. M. Cushman T. W. White J. D. Draves	76
Environmental Consequences of CO ₂ -Climate Interactions: The Need for Integrated Resource Analysis	Cushman, R. M. J. C. Waterhouse M. P. Farrell	75
An Evaluation of the Relationship Between the Production and Use of Energy and Atmospheric Methane Emissions	Barns, D. W. J. A. Edmonds	43

Title Index

	Page
Field Studies of Plant Responses to Elevated Carbon Dioxide Levels, 1980	125
	Rogers, H. H. G. E. Bingham J. D. Cure W. W. Heck A. S. Heagle D. W. Israel J. M. Smith K. A. Surano J. F. Thomas
Field Studies of Sweet Potatoes and Cowpeas in Response to Elevated Dioxide, 1985	125
	Biswas, P. K. J. R. Allen N. C. Bhattacharya J. Y. Lu R. D. Pace H. H. Rogers K. B. Coleman J. F. Eatman P. P. Ghosh N. Mbikayi J. N. McCrimmon A. Menefee
Flux of Organic Carbon by Rivers to the Oceans	129
	National Research Council
FORAST Database	117
	McLaughlin, S. B. D. J. Downing T. J. Blasing B. L. Jackson D. J. Pack D. N. Duvick L. K. Mann T. W. Doyle
GEOSECS Atlantic, Pacific, Indian, and Mediterranean Radiocarbon Data	96
	Östlund, H. G. M. Stuiver
Glaciers, Ice Sheets, and Sea Level: Effect of a CO ₂ -Induced Climatic Change	66
	Polar Research Board National Res. Council
The Global Carbon Cycle	134
	Carbon Dioxide Research Program, U.S. DOE
Global Change Acronyms & Abbreviations	83
	Woodard, C. T. F. W. Stoss

		Page
Global Change Research: Summaries of Research in FY 1992	Environmental Sciences Division, U.S. DOE	6
Global Change Research: Summaries of Research in FY 1993		8
Global Change Research: Summaries of Research in FY 1994		8
Global Climate Feedbacks: Proceedings of the Brookhaven National Laboratory Workshop	Manowitz, B.	132
Global Climate Trends and Greenhouse Gas Data: Federal Activities in Data Collection, Archiving, and Dissemination. A report to the Congress of the United States	Office of Environmental Analysis, U.S. DOE	68
Global 1 Degree by 1 Degree Distribution of Atmospheric/Soil CO ₂ Consumption by Continental Weathering and of Riverine HCO ₃ Yield	Suchet, P. A. J.-L. Probst	121
Global Distribution of Total Cloud Cover and Cloud Type Amounts Over Land	Warren, S. G. C. J. Hahn J. London R. M. Chervin R. L. Jenne	62
Global Distribution of Total Cloud Cover and Cloud Type Amounts Over the Ocean	Warren, S. G. C. J. Hahn J. London R. M. Chervin R. L. Jenne	64
Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones	Birdwell, K. R. R. C. Daniels	99
Global and Hemispheric Annual Temperature Variations Between 1861 and 1991	Jones, P. D. T. M. L. Wigley P. B. Wright	93
The Global Historical Climatology Network: Long-Term Monthly Temperature, Precipitation, Sea Level Pressure, and Station Pressure Data	Vose, R. S. R. L. Schmoyer P. M. Steurer T. C. Peterson R. Heim T. R. Karl J. K. Eischeid	102

Title Index

	Page
Global Lake-Level Variations from 18,000 to 0 Years Ago: A Palaeoclimatic Analysis	43
	Street-Perrott, F. A. D. S. Marchand N. Roberts S. P. Harrison
Global and Latitudinal Estimates of $\delta^{13}\text{C}$ from Fossil-Fuel Consumption and Cement Manufacture	121
	Andres, R. J. G. Marland S. Bischof
Global Paleoclimatic Data for 6000 Yr. B.P.	90
A Global Paleoclimatic Data Base for 6000 Year B.P.	21
Global Patterns of Carbon Dioxide Emissions from Soils on a 0.5 Degree Grid Cell Basis	122
	Raich J. W. C. S. Potter
Global, Regional, and National Annual CO_2 Emission Estimates from Fossil-Fuel Burning, Hydraulic Cement Production, and Gas Flaring: 1950–1992	97
	Marland, G. R. J. Andres T. A. Boden
Globally Averaged Atmospheric CFC-11 Concentrations: Monthly and Annual Data for the Period 1975–1992	120
	Khalil, M. A. K. R. A. Rasmussen
Glossary: Carbon Dioxide and Climate	77
	Carbon Dioxide Information Analysis Center
Goddard Institute for Space Studies (GISS) 3-Dimensional (3-D) Global Tracer Transport Model	117
	Fung, I.
Graduate Student Theses Supported by Carbon Dioxide Research Division Office of Basic Energy Sciences, U.S. Department of Energy	73
	Millemann, R. E.
Graduate Student Theses Supported by DOE's Environmental Sciences Division	65
	Cushman, R. M. B. M. Parra
A Grid-Point Surface Air Temperature Data Set for the Northern Hemisphere	24
	Jones, P. D. S. C. B. Raper B. Santer B. S. G. Cherry C. Goodess P. M. Kelly T. M. L. Wigley R. S. Bradley H. F. Diaz

		Page
A Grid-Point Surface Air Temperature Data Set for the Southern Hemisphere	Jones, P. D. S. C. B. Raper C. M. Goodess B. S. G. Cherry T. M. L. Wigley	26
Growth and Chemical Responses to CO ₂ Enrichment—Virginia Pine (<i>Pinus Virginiana</i> Mill.)	Luxmoore, R. J. R. J. Norby E. G. O'Neill D. G. Weller J. M. Ells H. H. Rogers	89
Handbook of Methods for the Analysis of the Various Parameters of the Carbon Dioxide System in Sea Water	Dickson, A. G. C. Goyet	82
High Accuracy Standards and Reference Methodology for Carbon Dioxide in the Air	Zielinski, W. L. Jr. E. E. Hughes I. L. Barnes J. W. Elkins H. L. Rook	31
Historic Land Use and Carbon Estimates for South and Southeast Asia: 1880–1980	Richards, J. F. E. P. Flint	105
Historical Carbon Dioxide: Abundances Derived from the Smithsonian Spectrograms	Stokes, G. M. J. C. Barnard E. W. Pearson	18
Historical Sunshine and Cloud Data in the United States	Steurer, P. M. T. R. Karl	93
ICRCCM Infrared (Clear-Sky) Line-by-Line Radiative Fluxes	Arking, A. B. Ridgway T. Clough M. Iacono B. Fomin A. Trotsenko S. Freidenreich D. Schwarzkopf	115
Identification, Recommendation, and Justification of Potential Locales for ARM Sites	Atmospheric and Climate Research Division, U.S. DOE	56
Identification, Recommendation, and Justification of Potential Locales for ARM Sites, Executive Summary	Atmospheric and Climate Research Division, U.S. DOE	55

Title Index

		Page
The IEA/ORAU Long-Term Global Energy CO ₂ Model	Edmonds, J. A. J. M. Reilly	110
The IEA/ORAU Long-Term Global Energy CO ₂ Model: Personal Computer Version A84PC	Edmonds, J. A. J. M. Reilly	111
The Impact of Climate Change from Increased Atmospheric Carbon Dioxide on American Agriculture	Decker, W. L. V. K. Jones R. Achutuni	30
Indian Ocean Radiocarbon: Data from the INDIGO 1, 2, and 3 Cruises	Östlund, H. G. C. Grall	100
<i>In situ</i> Carbon 13 and Oxygen 18 Ratios of Atmospheric CO ₂ from Cape Grim, Tasmania Australia: 1982–1993	Francey, R. J. P. P. Tans C. E. Allison I. G. Enting J. W. C. White M. Trolier	122
Intercomparison of Radiation Codes in Climate Models	American Geophysical Union	69
Intergovernmental Panel on Climate Change (IPCC), Working Group 1, 1994: Modelling Results Relating Future Atmospheric CO ₂ Concentrations to Industrial Emissions	Enting, I. G. T. M. L. Wigley M. Heimann	119
Major World Ecosystem Complexes Ranked by by Carbon in Live Vegetation: A Database	Olson, J. S. J. A. Watts L. J. Allison	91
Master Index for the Carbon Dioxide Research State-of-the-Art Report Series	Farrell, M. P.	62
Methods of Uncertainty Analysis for a Global Carbon Dioxide Model	Gardner, R. H. J. R. Trabalka	25
Modeling pCO ₂ in the Upper Ocean: A Review of Relevant Physical, Chemical, and Biological Processes	Archer, D.	45
Modeling the Response of Plants and Ecosystems to Elevated CO ₂ and Climate Change	Reynolds, J. F. D. W. Hilbert J. Chen P. C. Harley P. R. Kemp P. W. Leadley	50

		Page
Monthly Mean Pressure Reconstructions for Europe (Back to 1780) and North America (To 1858)	Jones, P. D. T. M. L. Wigley K. R. Briffa	35
Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980)	Jones, P. D. T. M. L. Wigley K. R. Briffa	94
Multi-Year Strategic Plan for the Atmospheric Studies in Complex Terrain (ASCOT) Program	Environmental Sciences Division, U.S. DOE	5
Natural and Accelerated Bioremediation Research (NABIR)	Office of Energy Research U.S. DOE	9
Natural Sinks of CO ₂	Wisniewski, J. A. E. Lugo	134
Newsletters (CDIAC)	Carbon Dioxide Information Analysis Center	135
Overview of the DOE Atmospheric Chemistry Program's Ozone Project	Environmental Sciences Division, U.S. DOE	7
Photosynthesis, Environmental Change, and Plant Adaptation—Research Topics in Plant Molecular Ecology	Offices of Health and Environmental Research and Basic Energy Sciences, U.S. DOE	51
A Plan for Intermodel Comparison of Atmospheric CO ₂ Projections with Uncertainty Analysis	King, A. W. M. J. Sale	75
Policy Statements on Data Management for Global Change Research	U. S. Global Change Research Program	68
On Possible Changes in Global Sea Level and Their Potential Causes	Barnett, T. P.	13
The Possible Direct Use of Satellite Radiance Measurements by the Atmospheric Radiation Measurement Program	Environmental Sciences Division, U.S. DOE	56
A Preliminary Analysis of U.S. CO ₂ Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010	Edmonds, J. A. W. B. Ashton H. C. Cheng M. Steinberg	42

Title Index

		Page
Preliminary Data Report for the INDIVAT Number 1 and INDIGO 1/INDIVAT 3 Cruises in the Indian Ocean	Chen, C.-T. A. A. Poisson G. Goyet	28
A Primer on Greenhouse Gases	Wuebbles, D. J. J. A. Edmonds	37
Proceedings of the Carbon Dioxide and Climate Research Program Conference	Schmitt, L. E.	129
Proceedings of the International Symposium on Ecological Aspects of Tree Ring Analysis	Jacoby, G. C. Jr. J. W. Hornbeck	131
Proceedings of the Second Atmospheric Radiation Measurement (ARM) Science Team Meeting	Environmental Sciences Division, U.S. DOE	57
Proceedings of the Third Atmospheric Radiation Measurement (ARM) Science Team Meeting	Environmental Sciences Division, U.S. DOE	57
Proceedings of the Fourth Atmospheric Radiation Measurement (ARM) Science Team Meeting	Environmental Sciences Division, U.S. DOE	57
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. An Overview	Rosenberg, N. J. P. R. Crosson	47
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report I. Background and Baselines	Rosenberg, N. J. P. R. Crosson K. D. Frederick W. E. Easterling III M. S. McKenney R. A. Sedjo M. D. Bowes J. Darmstadter L. A. Katz K. M. Lemon	47
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IIA. Agricultural Production and Resource Use in the MINK Region Without and With Climate Change	Crosson, P. R. L. A. Katz J. Wingard	47

		Page
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IIB. A Farm-Level Simulation of the Effects of Climate Change on Crop Production in the MINK Region	Easterling, W. E. III M. S. McKenney N. J. Rosenberg K. M. Lemon	48
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report III. Forest Resources	Bowes, M. D. R. A. Sedjo	48
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report IV. Water Resources	Frederick, K. D.	48
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project. Report V. Energy	Darmstadter, J.	49
Processes for Identifying Regional Influences of and Responses to Increasing Atmospheric CO ₂ and Climate Change—The MINK Project Report VI. Consequences of Climate Change for the MINK Economy: Impacts and Responses	Bowes, M. D. P. R. Crosson	49
Production of CO ₂ From Fossil Fuel Burning by Fuel Type, 1860–1982	Rotty, R. M. G. Marland	88
Projecting the Climatic Effects of Increasing Carbon Dioxide	MacCracken, M. C. F. M. Luther	61
A Proposed Reference Set of Scenarios for Radiatively Active Atmospheric Constituents	Wuebbles, D. J. M. C. MacCracken F. M. Luther	20
The Prospect of Solving the CO ₂ Problem Through Global Reforestation	Marland, G.	36

Title Index

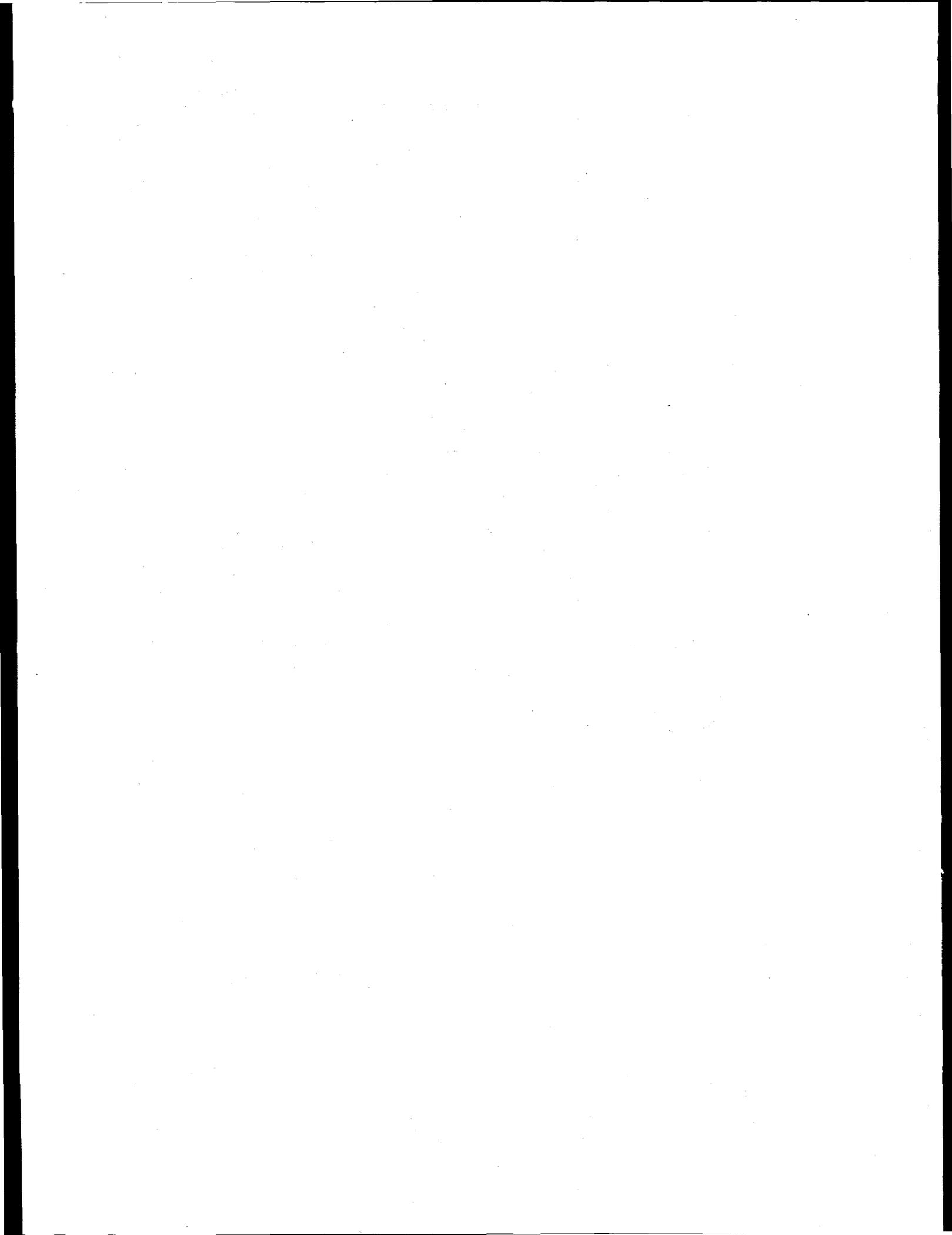
	Page
Quantifying and Minimizing Uncertainty of Climate Forcing by Anthropogenic Aerosols	67
	Penner, J. E. R. J. Charlson J. M. Hales N. Laulainen R. Leifer T. Novakov J. Ogren L. F. Radke S. E. Schwartz L. Travis
Rattlesnake Mountain Observatory (46.4° N, 119.6° W) Multispectral Optical Depth Measurements: 1979–1994	109
	Larson, N. R. J. J. Michalsky B. A. LeBaron
Reconstruction of Past Atmospheric CO ₂ Contents from the Chemistry of the Contemporary Ocean: An Evaluation	23
	Broecker, W. S. T. Takahashi T.-H. Peng
Regional Intercomparisons of General Circulation Model Predictions and Historical Climate Data	38
	Grotch, S. L.
A Report from the Second U.S./Japan Workshop on Global Change Research: Environmental Response Technologies (Mitigation and Adaptation)	131
	Edgerton, S. T. Mizuno
Report of the International Workshop on Quality Control of Monthly Climate Data	81
	National Climatic Data Center
Response of the North American Corn Belt to Climate Warming	16
	Blasing, T. J. A. M. Solomon
Response of Unmanaged Forests to CO ₂ -Induced Climate Change: Available Information, Initial Tests, and Data Requirements	17
	Solomon, A. M. M. L. Tharp D. C. West G. E. Taylor J. W. Webb J. L. Trimble
Review of Carbon Dioxide Research Staffing and Academic Support	66
	Clark, S. B. L. Howard W. Stevenson J. Trice
Science Plan for the Atmospheric Radiation Measurement Program (ARM)	57
	Environmental Sciences Division, U.S. DOE

		Page
Seasonal Climate Scenarios for Europe and North America in a High-CO ₂ , Warmer World	Palutikof, J. P. T. M. L. Wigley J. M. Lough	18
Selected Translated Abstracts of Russian-Language Climate-Change Publications. I. Surface Energy Budget	Ravina, C. B. M. D. Burtis	79
Selected Translated Abstracts of Russian-Language Climate-Change Publications. II. Clouds	Ravina, C. B. M. D. Burtis	80
Selected Translated Abstracts of Russian-Language Climate-Change Publications. III. Aerosols	Razuvaev, V. N. S. G. Sivachok	83
Simulating Climate with Two Different Numerical Schemes	Gutowski, W. J. M. J. Iacono X.-Z. Liang W.-C. Wang	44
Six- and Three-Hourly Meteorological Observations from 223 U.S.S.R. Stations	Razuvayev, E. G. E. G. Apasova R. A. Martuganov	107
Solar Records: The Wolf Sunspot Index and Umbral/Penumbral Ratio Budget	Hoyt, D. V.	91
The Stability of Low-Latitude Sea Surface Temperatures: An Evaluation of the CLIMAP Reconstruction With Emphasis on the Positive SST Anomalies	Prell, W. L.	25
Surface Energy Balance of Three General Circulation Models: Current Climate and Response to Increasing Atmospheric CO ₂	Gutowski, W. J. D. S. Gutzler D. Portman W.-C. Wang	39
Surface Water and Atmospheric Carbon Dioxide and Nitrous Oxide Observations by Shipboard Automated Gas Chromatography: Results From Expeditions Between 1977 and 1990	Weiss, R. F. F. A. Van Woy P. K. Salameh	104
A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S.	Steinberg, M. H. C. Cheng F. Horn	20

Title Index

	Page
Total Carbon Dioxide, Hydrographic, and Nitrate Measurements in the Southwest Pacific During Austral Autumn, 1990: Results from the NOAA/PMEL GCG-90 Cruise	Lamb, M. F. R. A. Feely L. Moore D. K. Atwood 109
Transient Tracers in the Oceans (TTO)— Hydrographic Data and Carbon Dioxide Systems with Revised Carbon Chemistry Data	Brewer, P. G. T. Takahashi R. T. Williams 87
Tree Ring Chronology Indexes and Reconstructions of Precipitation in Central Iowa, USA	Blasing, T. J. D. N. Duvick 87
Trends '93: A Compendium of Data on Global Change	Boden, T. A. D. P. Kaiser R. J. Sepanski F. W. Stoss 81
A Two Dimensional CO ₂ -Ocean Model Including the Biological Processes	Baes, C. F. Jr. G. G. Killough 23
Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China	Tao, S. C. Fu Z. Zeng Q. Zhang 101
Uncertainty in Future Global Energy Use and Fossil Fuel CO ₂ Emissions 1975 to 2075	Edmonds, J. A. J. M. Reilly R. H. Gardner A. Brenkert 34
United States Historical Climatology Network Daily Temperature and Precipitation Data	Hughes, P. Y. E. H. Mason T. R. Karl W. A. Brower 102
United States Historical Climatology Network (U.S. HCN) Monthly Temperature and Precipitation Data	Easterling, D. R. T. R. Karl E. H. Mason P. Y. Hughes D. P. Bowman 92

		Page
An Updated Global Grid Point Surface Air Temperature Anomaly Data Set: 1851–1990	Jones, P. D. S. C. B. Raper B. S. G. Cherry C. M. Goodess T. M. L. Wigley B. Santer P. M. Kelly R. S. Bradley H. F. Diaz	92
The Use of Statistical Climate-Crop Models for Simulating Yield to Project the Impacts of CO ₂ Induced Climate Change	Decker, W. L. R. Achutuni	41
Vegetation Response to Carbon Dioxide Research Plan	Dahlman, R. C.	3
Volcanic Loading: The Dust Veil Index	Lamb, H. H.	90
Worldwide Organic Soil Carbon and Nitrogen Data	Zinke, P. J. A. G. Stangenberger W. M. Post W. R. Emanuel J. S. Olson	91
Workshop on Environmental and Societal Consequences of a Possible CO ₂ -Induced Climate Change	Office of Health and Environmental Research	129
Workshop on Oceanic CO ₂ Standardization	Östlund, H. G. D. Dyrssen	129
Workshop on Sea Level Rise and Coastal Processes	Mehta, A. J. R. M. Cushman	130



Accessing CDIAC's Anonymous FTP Area

To access CDIAC's anonymous FTP files from your computer on Internet or another computer network, start at the monitor prompt on your network-node computer. At the monitor prompt (e.g., \$), type

```
$ftp cdiac.esd.ornl.gov or ftp 128.219.24.36
```

A prompt comes back,

```
Connected to cdiac.esd.ornl.gov
```

You will be asked for a user ID with the prompt

```
Name: (cdiac.trn):
```

```
Type
```

```
anonymous
```

You will then be asked for a password. Enter your complete e-mail address; for example,

```
Password: cdiac@ornl.gov
```

You should now be logged on. If the system does not accept your e-mail address as typed, try again with a hyphen in front of the e-mail address; for example,

```
Password: -ffo@ornl.gov
```

If this still does not work, make sure you are not trying to access our system through a gopher system and that you are not telneting to the anonymous ftp area (i.e, telnet cdiac.esd.ornl.gov).

The system will place you at the root directory of CDIAC's Anonymous area. You need to get to the subdirectory where the data and text files are stored. At the ftp> prompt, type

```
ftp>cd pub
```

The "cd" stands for "change directory"; cd pub will place you in the public-domain subdirectory. To check, type

```
ftp>dir
```

A listing will appear that names all the available numeric data packages (NDPs) and other files. At this point, copy the README and MASTER.LST files to your local computer and read them. To copy the file, type

```
ftp>get README  
ftp>get MASTER.LST
```

Select an NDP of interest, and type, for example,

```
ftp>cd ndp035
```

Note that the name of the subdirectory must be typed exactly as it appears in the listing, including a faithful reflection of the use of upper- and lower-case letters. Once in the new subdirectory, type

```
ftp>dir
```

and a listing of the files associated with the selected NDP will appear. The files have a variety of extensions associated with them; the normal symbolism of these extensions is

asc	ASCII files
e00	ARCINFO export files
for	FORTRAN retrieval codes
sas	SAS retrieval codes
bn	vector-coordinate files
des	README-file equivalents
dat	data files
his	station-history files
inv	station-inventory files
qa	quality-assessment files
tob	time-of-observation bias corrections

To look at just a certain type of file, use wildcards in the directory command. For example, to list all of the files with the extension asc, type

```
ftp>dir *.asc
```

To download one of these files, type

```
ftp>get filename
```

The CDIAC system will now transfer the file to your local computer. Note that all of these files have been compressed to save storage and transmission costs. (compression is designated with a "Z" as a final extension in the file name.) If you are using a UNIX or similar system, the file will be transmitted to you in a compressed format. After you have logged off the CDIAC computer, you will need to uncompress the file with the uncompress command on your local computer.

For example:

```
$uncompress filename
```

The resulting file will be one containing ASCII characters that you can use as though you created it yourself on your own system.

If your system does not support the uncompress command, the CDIAC computer will automatically sense this and will uncompress the file before transmitting it to you. The transmission will take longer, but you will still end up with a file you can use as though you created it yourself.

If you wish to download several files, you may wish to explore the use of the mget (multiple-get) command. Its operation is similar to that of the get command (e.g., mget *.* where *.* stands for the entire data files located within the subdirectory.)

When you are through working on the CDIAC computer, type

```
ftp>bye
```

to return to your local computer.

You should also be aware that comprehensive, written documentation is available for many of the databases, models, etc. in this anonymous FTP area. If you would like to receive any of these documents, or if you have any problems accessing CDIAC's anonymous ftp area, please contact Sonja Jones: cdiac@ornl.gov.

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