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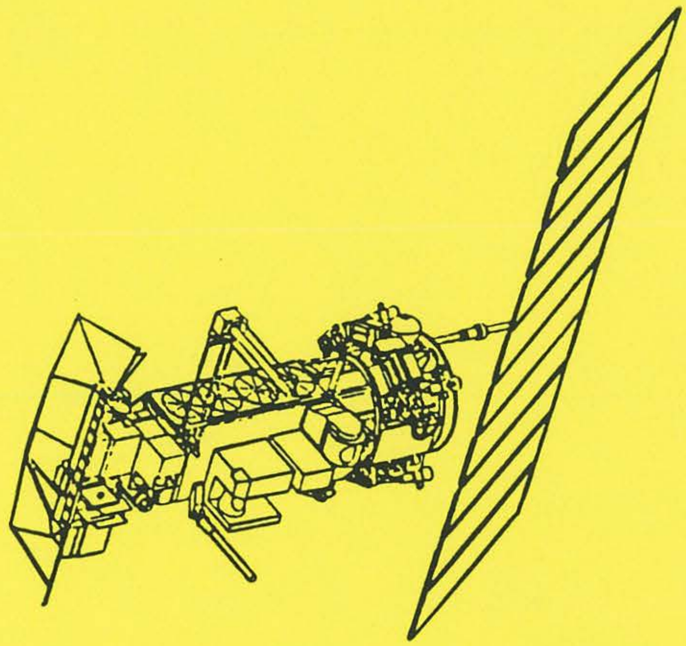

FEBRUARY 1990

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental, Satellite, Data, and Information Service
National Oceanographic Data Center

GLOBAL CLIMATE CHANGE:

A Selective Bibliography

FEBRUARY 1990

In January 1989, a report entitled Our Changing Planet: A U.S. Strategy for Global Change Research accompanied the President's FY 1990 Budget to the Congress. This report announced the beginning of the multi-agency U.S. Global Change Research Program, which will seek to improve understanding of the causes, processes, and consequences of the natural and human-induced changes in the global "Earth System."

NOAA is the scientific agency with operational and research responsibilities for monitoring and short-term prediction of the state of the atmosphere and the oceans. It now operates a majority of the long-term measurement systems that must be adapted to document change more effectively; it is deeply involved in research aimed at understanding specific global processes; it develops climate simulation and prediction models which incorporate some of our current understandings of those processes; and it operates a system of data centers on which an information system must be built.

This bibliography offers a selection of references to documents related to global climate change, the aspect of the U.S. Global Change Research Program of most direct concern to NOAA. It is not intended to be a comprehensive literature review, but rather to be a selective compilation of current citations retrieved from relevant databases, including Meteorological and Geoastrophysical Abstracts; DOE's Energy Data Base; National Technical Information Service; and Aerospace Data Base.

The bibliography is divided into 3 categories: (1) General Works; (2) Monitoring Global Change; and (3) Predicting Global Change. The citations are arranged in alphabetical order by author within these categories.

Questions about this material may be addressed to the Reference Desk, NOAA Central Library, 6009 Executive Boulevard, Rockville, MD 20852, or call (301) 443-8330.

General Works, Policy and Plans

1. American Meteorological Society.
The changing atmosphere--challenges and opportunities, prepared by the American Meteorological Society and the University Corporation for Atmospheric Research.
Boston, MA: American Meteorological Society, 24 p., 1988.

Abstract: Important opportunities are becoming available to decrease the risks to the nation from hazardous weather and global climate change, and to create economic advantages through better understanding and prediction. The AMS and UCAR recommend, as one of two top-priority actions, that the United States and other nations combine efforts to develop the observational data base, the computer models, and the understanding needed to anticipate the course of climate-related events, to estimate their impacts, and to prepare for future changes.

2. Beran, M. Inst. for Hydrol., Wallingford, Eng.
Water resource impact of future climate change and variability.
In: United States. Environmental Protection Agency/United Nations Environment Programme, Effect of Changes in Stratospheric Ozone and Global Climate, Vol. 1, Overview. Wash., D.C., Aug. 1986. p. 299-328. Refs., figs. (International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, June 16-20, 1986, Proceedings).

Abstract: An altered availability of water will be one of the more obvious impacts of climatic change. The author describes methods and models used by hydrologists to forecast the effect of climatic change on the availability of water for human consumption, irrigation, power production, effluent dilution, and navigation. This assessment requires two steps: the first concerns impact on hydrologic variables such as annual runoff; and the second is required to assess the impact in human terms and expresses the hydrologic variables in terms that quantify the exploitable fraction of the runoff. The literature is surveyed on both parts of this process. Causal, conceptual, and empirical models have been used to translate GCM and analog climate scenarios into hydrologic terms. Conceptual and empirical models have been applied to the additional task of modelling the consequences to water resource outputs, particularly the performance of storage reservoirs. In an alternative approach, an empirical model based on the storage yield diagram is used to quantify the impact on reservoir reliability of given changes to the mean and variability of reservoir inflows. To extend this approach to accommodate climatic rather than hydrologic change, the use of comparative hydrology techniques is advocated in which a future climate at a point is likened to the current climate elsewhere. The advantages and shortcomings of the various approaches are enumerated, and these give rise to a list of research suggestions and strategies for future impact studies. The few papers and reports devoted to the subject indicate that little attention has been given to the problem in the past. Interest has begun to increase since the scientific consensus on climatic change appears to have centered on a global warming induced by radiatively active gases. International organizations have an important role in coordinating the necessary effort.

3. Bolin, B. Dept. of Met., Univ. of Stockholm.
Greenhouse effect, climatic change, and ecosystems.
Chichester, Eng.: John Wiley & Sons. Published on behalf of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU) with the support of the United Nations Environment Programme and the World Meteorological Organization. (SCOPE 29), 541 p., 1986.

Abstract: This book is the result of the first international scientific assessment of the consequences of the continuing increase in the concentration of greenhouse gases in the atmosphere, which modify the radiative balance of the atmosphere. It addresses a number of questions that have been of major concern in recent years: the projection of energy use and increased emission of carbon dioxide by fossil fuel burning; the natural sources and sinks of carbon dioxide and their modification by deforestation and changing land use; the expected increase in the level of other greenhouse gases in the atmosphere; possible climatic change and its detection; sea level change and its detection; and the overall response of terrestrial ecosystems. The current knowledge of this important subject is summarized, and the main uncertainties and controversies that remain are presented. Scientists drawn from a number of disciplines contribute their own perspectives to the analysis of the problem, making the book of interest to meteorologists, climatologists, environmental scientists, and energy researchers.

4. Budyko, M. I. Gosud. Gidrol. Inst.
Klimat kontsa dvadtsatogo veka. [Climate at the close of the 20th century.]
Meteorologiya i Gidrologiya, Moscow, No. 10, p. 5-24, Oct. 1988. Transl. into English in corresponding issue of Meteorology and Hydrology, Wash., D.C. Available from NTIS, Springfield, VA. 22161.

Abstract: In relation to the organization of the cooperative Soviet-American investigation of future climatic conditions, a brief review of the results from some Soviet studies concerned with the problem of anthropogenic climate change is presented.

5.
Changing climate and the oceans.
Oceanus, Woods Hole, MA., Vol. 29, No. 4, Special Issue, Winter 1986/87.

Abstract: This special issue is concerned particularly with the role of the oceans in climate change, methods for investigating climate change, and evidence for climate change. The individual papers deal with the oceans, carbon dioxide, and climate change; biogeochemical cycles of the ocean; models of atmosphere-oceans as a means for studying climate change; the relationship of variation of the Earth's orbit, CO2 , and climate change; the polar ice sheets; information on climate change in marine cores; evidence for past climates, provided by pollen in marine cores; and the relationship between forests and climate. All the papers are nontechnical and are designed for the nonspecialist.

6. Chen, C. A.; E. T. Drake. Coll. of Ocean., OR. State Univ., Corvallis.
Carbon dioxide increase in the atmosphere and oceans and possible effects on climate.
In: Annual Review of Earth and Planetary Sciences, Vol. 14. Palo Alto, CA., p. 201-235, 1986.

Abstract: The current state of the CO2 problem is reviewed on the basis of the literature for the period 1978-1985. A brief overview of early theoretical considerations of the greenhouse effect, beginning with J. Fourier (1821), and of early observations on increases in atmospheric CO SUB 2 , beginning with S. Arrhenius (1896), is presented. This review covers 1) CO2

in the atmosphere, including the preindustrial level as determined from sampling of air bubbles in ice cores, from oceanic CO2 data, and from the tree-ring C-13 records; the rise in CO2 level-the Mauna Loa program; and modelling of future CO2 increases, including the carbon cycle, the fossil fuel contribution, and contributions from the biosphere; 2) the carbonate system in the oceans; carbonate chemistry, and distribution of carbon in the oceans; 3) temporal increase of CO SUB 2 in the oceans as determined from tracer studies (air-sea exchange and vertical mixing), and from direct carbonate data; 4) possible consequences of the rising atmospheric CO2 levels, effects of rising sea level, and social-economic political consequences; and 5) feasibility of delaying greenhouse warming, natural feedback mechanisms, and possible ways of mitigating the greenhouse effect.

7. Decker, W. L.; V. Jones; R. Achutuni. Dept. of Atmos. Sci., Univ. of MO., Columbia.
Impact of CO2 -induced climate change on U.S. agriculture.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0236, Dec. 1985.

Abstract: This chapter concentrates on the agricultural heartland in the Central U.S. and on the zone of moisture transition along the western margins of this region. This analysis should serve as a guide to similar surveys for other agricultural regions. The climate modellers have not yet been able to evaluate the impact of CO SUB 2 - induced climate change on climate variability which may increase the risks to agricultural production. These risks involve drought frequencies; the occurrence of lethal temperatures at both extremes; and the risks from pests, which develop under unusual weather conditions. The displacement and amplitude of the atmospheric circulation patterns may produce changes in the spatial and temporal patterns of the climatic risks. In mid-America, generally there has been an increase in climatic variability (year-to-year variations) since the mid-1970s.

8. Decker, W. L.; V. K. Jones; R. Achutuni. Dept. of Atmos. Sci., Univ. of MO., Columbia.
Impact of climate change from increased atmospheric carbon dioxide on American agriculture.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/NBB- 0077, May 1986.

Abstract: The development of agriculture in the U.S. in the 20th century, the resources in agricultural production, and the institutional support bases for American agriculture and crop production in the U.S. are described briefly. A detailed account of the impacts of climate change upon crop production is given by considering 1) the effects of CO2 -induced climate change on crop production in the corn belt, including the relationship of basic production and CO2 concentration, CO2 and photosynthesis, scenario for climate change, precipitation and soil moisture patterns, and growing degree days; 2) pressure for change in the distribution of crops in response to climate change as illustrated by corn vs. soy beans, corn vs. wheat, and corn vs. sorghum; 3) farm management alternatives for new climatic conditions; and 4) pest management. The impacts of climate change upon animal production are surveyed: 1) animals for food production in the U.S. Midwest; the impact of a CO2 -induced climate change upon animal production in the U.S. midwestern states, including direct climatic impact of CO2 -induced warming upon beef production, temperature stress in animals, rainfall as a determinant of crop and forage production, and humidity; and 2) animal management, involving controlled environments and animal health, genetics of animals, and impacts of climate upon forage production. The state of knowledge on weather and climatic impacts upon agriculture, and continued research and needs development are summarized.

9. Farrell, M. P. (ed.). Oak Ridge Natl. Lab., TN.
Master index for the carbon dioxide research state-of-the-art report series.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0316, 253 p., March 1987.

Abstract: This volume provides a master index to the four state-of-the-art (SOA) reports published by the U.S. Department of Energy's Carbon Dioxide Division. These reports are ''Atmospheric Carbon Dioxide and the Global Carbon Cycle''; ''Direct Effects of Increasing Carbon Dioxide on Vegetation''; ''Detecting the Climatic Effects of Increasing Carbon Dioxide''; and ''Projecting the Climate Effects of Increasing Carbon Dioxide''; and the two companion reports; ''Characterization of Information Requirements for Studies of CO SUB 2 Effects: Water Resources, Agriculture, Fisheries, Forests, and Human Health''; and ''Glaciers, Ice Sheets, and Sea Level: Effect of a CO2 -Induced Climatic Change''. These reports were produced in Feb. 1986, March 1986, Feb. 1986, April 1986, and Oct. 1985. The volume contains executive summaries of each of the aforementioned reports: a glossary of terms; tables of units; conversion factors; useful quantities in CO SUB 2 research etc.; a glossary of acronyms; indexes of common scientific names of flora and fauna mentioned in the six CO SUB 2 state-of-the-art reports; a citation index; and a subject index.

10. Federal Coordinating Council for Science, Engineering and Technology. Committee on Earth Sciences.
Our changing planet: a U.S. strategy for global change research: a report by the Committee on Earth Sciences to accompany the U.S. President's fiscal year 1990 budget.
Washington, D.C.: The Committee, 38 p., 1988.

Abstract: Global changes can have tremendous impact on human welfare. Responding to these changes without a strong scientific basis could be futile and costly. This report presents an initial strategy for a comprehensive, long-term U.S. Global Change Research Program. The goal of the program is to provide a sound scientific basis for developing national and international policy on global change issues. The program encompasses the full range of earth system changes, including both natural phenomena and the effects of human activity. The program is described in terms of seven interdisciplinary science elements. Budget information is summarized by agency and type of activity.

11. Federal Coordinating Council for Science, Engineering and Technology.
Committee on Earth Sciences.
Our changing planet: The FY 1990 research plan, a report by the Committee on Earth Sciences, the U. S. Global Change Research Program.
Washington, D.C.: The Committee, 1 v., various pagings, Figs., 1989.

Abstract: The scientific objectives of the research plan are to monitor, understand, and ultimately predict global change. The report outlines a priority framework for focusing and integrating the interagency research effort to ensure that they meet these objectives. This priority framework was derived from numerous research priorities outlined by both the U.S. and the international communities. In addition to the research plan, detailed budget information and information on agency roles are included.

12. Firor, J. W.
The heating up of the climate.
In: The Earth's Fragile Systems: Perspectives on Global Change.
Boulder, CO: Westview Press, p. 52-79, 1988.

Abstract: The greenhouse effect and its causes are described together with efforts to develop predictive models, their verification and deficiencies. A number of policy responses are proposed to allow a smooth transition to the incompletely understood, but surely different, climate likely to be experienced in the next century. These include reducing dependency on fossil fuels; more efficient energy use; decreased use of long-lived chlorofluorocarbons; searching for explanation of the increase in atmospheric methane, nitrous oxide, and ozone; improving irrigation systems and increasing agricultural research and development; and building regional food reserves and other forms of flexibility into national plans.

13. Flavin, C.
Slowing global warming: a worldwide strategy.
Washington, D.C.: Wordwatch Institute, 94p., 1989

Abstract: Only a movement away from fossil fuels will prevent climate change during the next century. The transition to renewable energy sources should begin at once and will extend over several decades. Target figures for reduction in per capita carbon emissions are proposed which should produce a 12 percent cut in emissions by the year 2000.

14. Gleick, P. H. Energy and Resources Group, Univ. of CA., Berkeley.
Methods for evaluating the regional hydrologic impacts of global climatic changes.
Journal of Hydrology, Amsterdam, 88(1/2): 97-116, Nov. 15, 1986. Refs.

Abstract: Concern over changes in global climate caused by rising atmospheric concentrations of carbon dioxide and other trace gases has increased in recent years as the understanding of atmospheric dynamics and global climate systems has improved. Yet, despite a better understanding of climatic processes, many of the effects of human-induced climatic changes are still poorly understood. The most profound effect of such climatic changes may be major alterations in regional hydrologic cycles and changes in regional water availability. Unfortunately, these are among the least well-understood impacts. Approaches for evaluating the regional hydrologic impacts of global climatic changes are reviewed and a series of criteria for choosing among the different methods is presented. One approach, the use of modified water balance models, appears to offer significant advantages over other methods in accuracy, flexibility, and ease of use. Water balance models are especially useful for identifying the regional hydrologic consequences of changes in temperature, precipitation, and other climatic variables. The ability of water balance models to incorporate month- to-month or seasonal variations in climate, snowfall and snowmelt algorithms, groundwater fluctuations, soil moisture characteristics, and natural climatic variability makes them especially attractive for water resource studies of climatic changes. Furthermore, such methods can be combined with state-of-the-art information from general circulation models of the climate and with plausible hypothetical climate change scenarios to generate information on the water resource implications of future climatic changes.

15.
Global Climate Change Digest, 1(1)- , Jan. 1988-
New York: Elsevier Science Publishing Co., Inc.

Abstract: This monthly newsletter provides access to technical and general information related to climate change resulting from human activities, particularly global warming by greenhouse gases and ozone depletion. It aims to encourage communication across disciplines and among interested parties at the national and international levels through annotated literature citations, news, and a calendar of conferences and other activities.

16. Gorshkov, S. P.
Problema CO2 : peresmotr idey. [CO2 problem: review of ideas.]
Vsesoyuznoye Geograficheskoye Obshchestvo, Leningrad, Izvestiya, 118(4): 297-305, July/Aug. 1986. Refs., tables.

Abstract: This paper surveys, on the basis of a review of the more recent literature in Russian and English, current ideas on the CO2 problem. The discussion includes data on the atmospheric concentration of carbon dioxide; secular trends of the effect of CO2 on climate, indicating the possibility of not only a warming but also a cooling effect; prospects of increase in productivity and drought resistance of plants, including the fertilizer effect of CO2 ; increase of the scales of nitrogen fixation in the soil in places of growth of bean crops; weeds; reduction of transpiration; and scales of anthropogenic reduction of the biosphere.

17. Green, B.
Policies on global warming and ozone depletion.
Environment, 29(3):5, 45, Apr 1987.

Abstract: The recent discovery of a dramatic seasonal drop in the amount of ozone over Antarctica has catalyzed concern for protection of stratospheric ozone, the layer of gas that shields the entire planet from excess ultraviolet radiation. Conservative scientific models predict about a 5% reduction in the amount of global ozone by the middle of the next century, with large local variations. The predicted global warming from increased emissions of greenhouse gases will also have differing effects on local climate and weather conditions and consequently on agriculture. Although numerous uncertainties are associated with both ozone depletion and a global warming, there is a consensus that world leaders need to address the problems. The US Congress is now beginning to take note of the task. In this article, one representative outlines some perceptions of the problems and the policy options available to Congress.

18. Hoffman, J. S. U.S. EPA, Wash., D.C.
Importance of knowing sooner.
In: United States. Environmental Protection Agency/United Nations Environment Programme, Effect of Changes in Stratospheric Ozone and Global Climate, vol. 1, Overview. Wash., D.C., Aug. 1986. p. 53-58. Refs. (International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, June 16-20, 1986, Proceedings).

Abstract: Unlike most environmental problems, greenhouse warming and ozone depletion are global in extent, have enormous momentum for change, and may be almost irreversible when they occur. Recent scientific assessments uniformly agree that the changes likely to occur

in the 20th century will exceed the range of natural variation experienced in the whole 19th century. Given the relative ignorance of the possible effects of these changes, it would appear that the value of knowing the effects sooner is substantial.

19. International Council of Scientific Unions, Paris (France).
International geosphere-biosphere program: a study of global change. Final report. NTIS No: PB-88-142393/XAB, 27 p., 4 Aug 1986.

Abstract: A better understanding of the Earth and its immediate environment is essential if we are to improve our ability to detect and to respond to warnings of significant global change. Although the world community of scientists has in the last 30 years successfully completed a wide range of international programs. The program will be tightly focused, with emphasis on interactive processes that are not addressed by other existing programs. Topics suggested for early emphasis in the IGBP include: (1) studies of biogeochemical cycles; (2) studies of the ocean euphotic zone; (3) studies of soil dynamics and soil chemistry; and (4) studies of variable solar inputs to the Earth. Emphasis is also put on the need for development of an adequate global data and information system, which must be an integral part of the program.

20. IOC/SCOR Committee on Climatic Changes and the Ocean, Paris.
Summary report: seventh session, Paris, 14-21 January 1986 102 p., 1986.

Abstract: This report summarizes the proceeding of the meeting of the Committee on Climatic Changes and the Ocean, held in Paris, Jan. 14-21, 1986. The individual papers report on WCRP (World Climate Research Program) ocean data management, planning and development of ocean observing programs for climate research, including the review of actions undertaken by the Intergovernmental Ocean Commission (IOC) and WMO in response to the Ocean Observing Systems Development Program; secular change in sea level; ocean-atmosphere boundary layer research; review of the Tropical Ocean and Global Atmosphere (TOGA) program; review of the planning for the World Ocean Circulation Experiment; proposals for ocean carbon dioxide research and monitoring, etc.

21. Jaeger, J. Beijer Inst., Stockholm.
Developing policies for responding to climatic change: a summary of the discussions and recommendations of the workshops held in Villach (28 September-2 October 1987) and Bellagio (9-13 November 1987), under the auspices of the Beijer Institute, Stockholm.
World Meteorological Organization, Geneva, World Climate Programme Impact Studies, WCIP-1. 53 p., Figs. (WMO/TD-No. 225), April 1988.

Abstract: This document summarizes the discussions held in 1987 in Villach, Austria, and in Bellagio, Italy, on the development of policies for responding to climatic change. Section 1 contains a summary of the scientific consensus on the greenhouse gases and climatic change reached at Villach. Section 2 examines possible scenarios for future changes in climate, temperature, and sea level in response to continuous emissions of greenhouse gases, and considers the uncertainties in the forecasting of global climatic change and the regional response to climatic change. Section 3 considers the effects of climatic change upon the latitudinal regions, such as oceans and coastal areas (erosion of beaches and coastal margins, land-use changes, wetlands loss, frequency and severity of flooding, damage to coast structures and port facilities, and damage to water management systems); the mid-latitude regions; the semiarid tropical regions; the humid tropical regions; and the high-latitude regions. Section 4 discusses response to climatic change; adaptation and limitation, including constraints on adaptation and the limitation of climate change; the use of rates of climatic change as a management tool; the timing of responses to climatic change; the cost of responding to climatic change; and policies for responding to climatic change.

22. Jung, H. J.; W. Bach. Ctr. for Applied Climatol. and Environ. Studies, Dept. of Geog., Univ. of Munster, W. Germany.
Effects of model-generated climatic changes due to a CO2 doubling on desertification processes in the Mediterranean area.
In: Fantechi, Roberto; Margaris, N. S. (eds.), Desertification in Europe. Dordrecht, Holland, D. Reidel Publ. Company, p. 35-48, 1986.

Abstract: For the estimation of a climatic change induced by a doubling of atmospheric CO_2, the results of three-dimensional general circulation models (GCM) are used. Although the results from present climate modelling cannot be considered as predictions of future climatic conditions because of the models' inherent deficits, they can still serve a useful purpose in climate change scenarios. The reason for this is that climate models are the only tools available to study the response of the climate system to a perturbation in a physically consistent manner and that such types of models can provide a consistent data set of high temporal and spatial resolution. For the Mediterranean area, the results obtained from three different GCMs, the British Meteorological Office model (BMO), the Goddard Institute of Space Studies model (GISS), and the National Center for Atmospheric Research model (NCAR), are shown. The regional and seasonal distributions of temperature, precipitation, and soil moisture are used to study the potential for desertification. The results indicate that the CO_2 -induced changes for temperature generated by the three models are quite similar. The values of the area mean change range between 2.5 and 4.2 K. The precipitation response results in a diverse pattern. The physical mechanisms likely to be responsible for the climatic changes are identified, and their statistical significance is tested. This type of work will aid in developing the methodology and assistance to gain insight into the use of climate model scenarios for impact analysis.

23. Jutro, P. R.; R. C. Worrest; A. C. Janetos. Environmental Protection Agency, Washington, DC. Office of Research and Development.
Scientific linkages in global change. NTIS No.:PB90-112608/XAB, 18 p., 16 Jun 89.

Abstract: In the atmosphere, certain trace gases both promote global warming and deplete the ozone layer. The primary radiatively active trace gases which affect global warming are carbon dioxide, nitrous oxide, chlorofluorocarbons, methane, and tropospheric ozone. In the troposphere, the atmosphere up to 10 miles above the earth's surface, these compounds function as greenhouse gases. Many of these gases also influence the concentration of ozone in the stratosphere, the atmospheric layer located between 10-30 miles above the earth's surface. The diffuse layer of ozone in the stratosphere protects life on earth from harmful solar radiation. A reduction of the layer could have very important impacts on the earth's systems. Interactions exist in various ecological processes as well. Physical, chemical, and biological activities of plants and animals are affected directly by global climate change and by increased ultraviolet radiation resulting from depletion of stratospheric ozone.

24. Kerr, R. A.
Greenhouse warming still coming.
Science, Wash., D.C., 232(4750): 573-574, May 2, 1986.

Abstract: The growing amount of carbon dioxide in the Earth's atmosphere from the burning of fossil fuels and deforestation looms as

a far larger and more pervasive problem than acid rain. A major scientific review by the Department of Energy has found that nearly a decade of research has not diminished the dimensions of the problem or, unfortunately, all the uncertainties. Current models predict a global warming of 1°C relative to the year 1850 by the year 2000. Increasing carbon dioxide would cause an additional warming of 2-5°C during the next century.

25. Kondrat'ev, K. I. Institut Ozerovedeniia, Leningrad, USSR.
International Geosphere-Biosphere Program - the role of space-based observations.
Issled. Zemli Kosmosa (USSR), p. 104-118, Aug 1987.

Abstract: The key environmental problems treated by the International Geosphere-Biosphere Program are examined. Proposals are outlined for the optimal planning and implementation of a global survey system designed to monitor geospheric and biospheric conditions. Particular consideration is given to the optimization of space remote-sensing conditions. 41 references.

26. Kondratyev, K. Y. Lab. of Remote Sensing, Inst. for Lake Res., Acad. of Sci.,Leningrad, U.S.S.R.
Key problems of environmental studies: International Geosphere-Biosphere Programme.
Zeitschrift fur Meteorologie, Berlin, 35(6): 309-313, 1985. Refs. English and German summaries.

Abstract: In relation to the development of the International Geosphere-Biosphere Programme (IGBP), key problems of the environment are discussed to specify major objectives of the IGBP as a program on studies of the interactive evolution of the geosphere and biosphere under conditions of increased anthropogenic impact. Taking into consideration extensive international programs in particular, the World Climate Programme and the Man and Biosphere Programme, the problem of global biogeophysical cycles of carbon, sulfur, nitrogen, phosphorus, and other elements must be considered as a key component of the IGBP. The processes determining the formation of biogeophysical cycles are responsible for anthropogenically induced changes in the atmospheric composition which, in turn, can cause changes in the climate and a depletion of the ozone layer, which protects the biosphere. Ideas are proposed for a global observational system to monitor the development of processes in the geosphere and biosphere.

27. Lockwood, J. G. School of Geog., Univ. of Leeds, Eng.
Changing atmospheric carbon dioxide.
Progress in Physical Geography, London., 11(4): 581-589, Dec. 1987.

Abstract: This paper reviews, on the basis of publications that have appeared in the period 1981-1987, the current state of knowledge on the increasing CO SUB 2 concentration of the atmosphere accompanied by a simultaneous rise in global mean temperature; the types of climatic models used by workers in this field to simulate the change in equilibrium climate resulting from an increase in CO2 concentration; and projections of future increase in atmospheric CO SUB 2 concentration and temperature increase. There are then summarized selected studies on the impacts of increased atmospheric CO2 concentration on spatial shifts of cropping patterns; reduction in zonal mean soil moisture over extensive midcontinental regions in the American and Eurasian Continents; the variable response to increased CO2 in the atmosphere by plants as determined by short crops, stomatal characteristics, and transpiration rates; the possibility that, in continental interiors, moderately freely evaporating vegetations will modify the temperature and humidity gradients in the lower atmosphere so as to keep shower activity in operation; and the effect of increasing atmospheric CO SUB 2 concentration in altering freshwater resources and upon sea level. Studies on the current state of knowledge on geological-scale climatic change and atmospheric CO2 are reviewed.

28. Manton, M. J. Bur. of Met. Res. Ctr., Melbourne.
Ninth meeting of the Joint Scientific Committee for the World Climate Research Programme.
Search, Sydney., 19(3): 121-122, May/June 1988.

Abstract: The ninth annual meeting of the JSC was held during March 14-19, 1988, in Fort Lauderdale, FL. The WCRP is structured with three streams of activity based upon time scales. The first stream has the objective of establishing the physical basis of atmospheric fluctuations on time scales of a few weeks. The second stream aims at the prediction of climate variations to a few years ahead, while stream three is concerned with time scales to several decades ahead. A fundamental element in all three streams of the WCRP is the development of climate models. In cooperation with the WMO, the JSC has convened a working group on numerical experimentation (WGNE), which promotes activities on the development and testing of numerical climate models.

29. Meleshko, V. P. Ob''yedinennaya Gruppa Planirovaniya VPIK, WMO/MSNS, Geneva,Switzerland.
Vsemirnaya programma issledovaniya klimata: obzor tseley i potrebnost' v dannykh. [World program for investigation of climate: review of goals and data requirements.]
Mezhdunarodnyy Simpozium, 1, Kompleksnyy Global'nyy Monitoring Mirovogo Okeana, Tallinn, Estonian S.S.R., Oct. 2-10, 1983: Trudy, tom 1. Leningrad, Gidrometeoizdat, p. 104-113, 1985. Refs. Russian summary.

Abstract: The goals of data requirements concerning the World Program of Climate Investigation, the nature of projects developed or fulfilled hitherto, and a new plan for investigating climate are surveyed. The fundamental goals are outlined; the problem of climate prediction is reviewed; the observational program of UNEP is described; and data requirements for climate investigation are presented.

30. Mintzer, I. M.
Matter of degrees: the potential for controlling the greenhouse effect.
Wash., D.C.: World Resources Institute, 64 p., 1987.

Abstract: Continuing pollution of the atmosphere seriously threatens the Earth's climate, with global mean temperatures expected to rise higher than ever before in the 8000 yr of recorded history. This study uses a new computer model to analyze the impacts of policy changes and new technologies upon the buildup of CO2 and other greenhouse gases in the atmosphere. Four scenarios were constructed to investigate how these policies and technologies can affect the future buildup of greenhouse gases and, thus, the extent of global warming. The scenarios include a base case in which no policies are introduced to arrest the buildup, and a slow buildup, in which strong policies are adopted to improve energy efficiency, introduce solar energy, discourage the use of carbon intensive fuels, and arrest deforestation. Conclusions emerging from the analysis suggest that 1) the base case scenario could raise the Earth's temperature by a whopping 2.9 to 8.6°C by the year 2075, and 2) the immediate implementation of strong policy measures can prevent drastic climate changes during the coming century, and can significantly affect the timing and acceleration of global warming.

31. Morrisette, P. M. (ed.). Natural Hazards Res. and Applications Information Ctr., Univ. of CO., Boulder.
Selected annotated bibliography of climate and society research.
United States. National Oceanic and Atmospheric Administration, National Climate Program Office, Rockville, MD., Technical Report (NOAA TR NCPO 002), 104 p., Sept. 1987.

Abstract: This bibliography contains 281 annotated references forming a selective review of investigations on the interaction of climate and society, with particular regard to the impact of fluctuations or changes of climatic conditions upon natural resource and socioeconomic systems and to the means by which society responds and adjusts to these changes. The bibliography is divided into eight sections, i.e., agriculture; water resources; environmental impacts; energy; commercial, industrial, and multiple impacts; climate and history; policy, decisionmaking, and perception; and theory, research assessments, and techniques.

32. National Aeronautics and Space Administration, Washington, DC.
Earth System Science: A Program for Global Change, 305 p. 1989.

Abstract: The Earth System Sciences Committee (ESSC) was appointed to consider directions for the NASA Earth-sciences program, with the following charge: review the science of the Earth as a system of interacting components; recommend an implementation strategy for Earth studies; and define the role of NASA in such a program. The challenge to the Earth system science is to develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity. Sustained, long-term measurements of global variables; fundamental descriptions of the Earth and its history; research foci and process studies; development of Earth system models; an information system for Earth system science; coordination of Federal agencies; and international cooperation are examined.

33. National Research Council, Commission on Physical Sciences,Mathematics, and Resources, Board on Atmospheric Sciences and Climate, Wash., D.C.
National Climate Program: early achievements and future directions. Report of the Woods Hole Workshop, July 15-19, 1985, 55 p. 1986.

Abstract: The aim of this workshop was to review the current federal efforts in climate investigations and to develop concepts and recommendations that might assist the federal agencies and the National Climate Program Office in developing an updated plan for the National Climate Program. The individual chapters of this report deal with 1) climate program policy issues, including the provisions of the National Climate Program Act, climate data management, drought policy, application of impact assessment policy, the social and institutional implications of climate forecasting, water resources and climates, and international cooperation; 2) climate systems research from 1978 to 1985, priorities for the future, and observational systems; 3) climate impacts, areas for specific initiatives, and institutional issues; and 4) climate data, information, and services.

34. National Research Council, Commission on Physical Sciences,Mathematics, and Resources.
Toward an international geosphere-biosphere program: a study of global change. [Report of a National Research Council Workshop, Woods Hole, MA., July 25-29, 1983.]
Wash., D.C.: National Academy Press, 81 p., 1983. Figs., tables, appendices.

Abstract: This workshop reviewed the major problems for research in the atmosphere, oceans, lithosphere, biosphere, and solar-terrestrial relationships. A unifying theme is global change. Beyond the intellectual drive to understand basic scientific interrelationships is the practical need to gain a better understanding of how to manage the environment and global life-support systems. A majority conclusion was reached that an International Geosphere-Biosphere Program (IGBP), under the auspices of the International Council of Scientific Unions (ICSU), could provide an effective vehicle for coordinating global measurements from space platforms and ground-based observational networks, exploiting new technologies for observations, implementing improved capabilities for data management, and placing proper emphasis on mathematical modelling with advanced computational facilities. Unlike the comparatively short-lived International Geophysical Year (IGY), an IGBP must be designed as a long-range, interdisciplinary program. Effective planning over the coming several years could inaugurate a program that would begin to take shape toward the end of this decade and reach maturity in the 1990s. The workshop participants urged that such planning begin immediately within national organizations and in all the interested adhering bodies of ICSU. An important target date for a first assessment of plans submitted from all sources would be the ICSU General Assembly in Sept. 1984. In implementing in IGBP, careful attention must be paid to all relevant national and international programs already conceived and in various stages of progress. Proper planning should guarantee that these programs continue to operate effectively. The success and timeliness of an IGBP are in large part predicted on continued understanding as well as a desire for greater interaction between neighboring disciplines starting to emerge from these programs.

35. National Research Council, Washington, DC.
Toward an Understanding of Global Change: Initial Priorities for U.S. Contributions to the International Geosphere-Biosphere Program. Final rept, 226 p. Dec 88. NTIS No.:PB89-231344/XAB.

Abstract: The report recommends a limited number of high-priority research initiatives for early implementation as part of the U.S. contribution to the preparatory phase of the International Geosphere-Biosphere Program. The recommendations are based on the committee's analysis of the most critical gaps in the scientific knowledge needed to understand the changes that are occurring in the earth system not being addressed by existing programs. The report articulates a number of important key issues and interactions that characterize global change in the geosphere-biosphere system on time scales of decades to centuries; identifies the knowledge that is the most urgently needed to improve understanding of those issues and interactions; and formulates initial priorities for initial U.S. contributions to the IGBP, recognizing the contributions of other ongoing and proposed programs.

36. Nierenberg, W. A.; R. Jastrow; F. Seitz
Scientific perspectives on the greenhouse problem.
Washington, D.C.: George C. Marshall Institute, 37 p., 1989

Abstract: On the basis of the large degree of uncertainty which still surrounds the nmerous predictions from the greenhouse effect, the authors suggest that is is too soon to begin making the enormous economic investment that would be needed to reduce the projected buildup of greenhouse gases.

37. O'Neill, R. V. Oak Ridge National Lab., TN.

Hierarchy theory and global change.
Workshop on Global Change, St. Petersburg, FL, USA, 28 Oct 1985.Department of Energy, Wash., D.C., 27 p., 1985.

Abstract: Hierarchy theory asserts that a useful way in which to deal with complex, multiscaled systems is to focus on a single phenomenon and a single time-space scale. By so limiting the problem, it is possible to define it clearly and choose the proper system to emphasize. This paper applies the theory to the problem of global change. 24 refs. (ERA citation 11:020857).

38. Parker, D. E.; C. K. Folland. Met. Off., Bracknell.
Nature of climatic variability.
Meteorological Magazine, Bracknell, Eng., 117(1392): 201-210, July 1988.

Abstract: Climatic variability results not only from the complex dynamics of the atmosphere but also from feedbacks involving the atmosphere, the oceans, the biosphere, and ice and snow. External influences, such as solar changes, volcanic eruptions, and man-made pollution, may also influence climate. Observed variations range in time scale from daily weather fluctuations to pronounced interdecadal changes of temperature, rainfall, and atmospheric circulation. The longer term changes may involve changes in variability as well as in average conditions. Except for the very shortest time scales, local and regional variations of weather and climate cannot be understood without considering the whole globe. Examples of observed climatic variations are used to amplify the above remarks. The possibility of climatic prediction is discussed. Improved understanding of the Earth's complex climatic system is prerequisite for useful climatic prediction, and the need for further observational and modelling research is clear.

39. Ramanathan, V. Dept. of the Geophys. Sci., Univ. of Chicago, IL.
Greenhouse theory of climate change: a test by an inadvertent global experiment.
Science, Wash., D.C., 240(4850): 293-299, April 15, 1988.

Abstract: Since the dawn of the industrial era, the atmospheric concentrations of several radiatively active gases have been increasing as a result of human activities. The radiative heating from this inadvertent experiment has driven the climate system out of equilibrium with the incoming solar energy. According to the greenhouse theory of climate change, the climate system will be restored to equilibrium by a warming of the surface- troposphere system and a cooling of the stratosphere. The predicted changes, during the next few decades, could far exceed natural climate variations in historical times; therefore, the greenhouse theory of climate change has reached the crucial stage of verification. Surface warming as large as that predicted by models would be unprecedented during an interglacial period such as the present. The theory, its scope for verification, and the emerging complexities of the climate feedback mechanisms are discussed.

40. Reichle, D. E.; J. R. Trabalka; A. M. Solomon. Environ. Sci. Div., Oak Ridge Natl. Lab., TN..
Approaches to studying the global carbon cycle.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0239, p. 15-24, Dec. 1985. Refs., figs. Available from NTIS, Springfield, Va. 22161

Abstract: This chapter describes the approaches that were used to formulate research on the global carbon cycle, and is designed principally to orient the nonspecialist. Topics include information exchange; analysis of existing data; monitoring; experimentation; and modelling.

41. Revell, R.; F. Bretherton. Univ. of CA.
Global'nyy monitoring okeana v tselyakh vsemirnoy klimaticheskoy programmy. [Global monitoring of the ocean for the World Climate Program.]
Mezhdunarodnyy Simpozium, 1, Kompleksnyy Global'nyy Monitoring Mirovogo Okeana, Tallinn, Estonian S.S.R., Oct. 2-10, 1983: Trudy, Tom 1. [Proceedings of the 1st International Symposium on Integrated Global Ocean Monitoring, vol. 1.] Leningrad, Gidrometeoizdat, p. 49-61, 1985. Figs. Russian summary.

Abstract: In relation to the oceanographic part of the World Climate Program, two oceanographic operations are described and proposed by the authors: study of the world ocean circulation, and investigation of the interannual variability of oceans in the tropical zone and of the planetary atmosphere. The scope of the program of investigation of the circulation, the theoretical and observational knowledge underlying such a program, and the planning of experiments for these programs, including instrumentation and subjects to be studied, are reviewed. The concept of the World Climate Program is divided into three courses of measures. Course 1: physical bases for long-range prediction of weather anomalies; course 2: interannual variability of the global atmospheric climate and of the tropical oceans; and course 3: long-range variability and sensitivity of the climate system to external influences. The authors discuss the programs of observational systems in the ocean, the fundamental assumptions underlying the World Climate Program, the data measurement procedures, and requirements for the three courses.

42. Risser, P. G. Univ. of N.M., Albuquerque.
Scientific Committee on Problems of the Environment and Global databases.(ICSU)
In: Building databases for global science: Proceedings. International Geographical Union Global Database Planning Project, Hampshire, Eng., May 9-13, 1988, London, Eng.: Taylor & Francis, 1988, p. 340-346.

Abstract: This article sets forth the purpose of SCOPE (Scientific Committee on Problems of the Environment) and describes other current SCOPE activities of particular interest to the Global Database Planning Project, such as ecotones, which constitute transitional areas of the biosphere, e.g., the transitional area between a forest and grassland or between a forest and a stream; the International Geosphere Biosphere Program; long-term ecological research; and the application of scientific information for sustainable development.

43. Roberts, L.
Is there life after climate change?
Science, Wash., D.C., 242(4881): 1010-1012, Nov. 18, 1988.

Abstract: How will the Earth's biota respond to the predicted greenhouse warming? If the climate models are correct, within 50 or 100 yr the Earth will be hotter than it has been in the past 1 million yr. Will plants be able to adjust, either physiologically or behaviorally, to the altered regime? Will they have to migrate to cooler climes? Or will they perish? The current view is that

biological communities will be disrupted, ranges will shift, and some species will become extinct. Globally, biological diversity will diminish. The warming will be greatest at higher latitudes, which spells trouble for the Arctic tundra and numerous species, such as migratory birds, that depend upon it. Atmospheric carbon dioxide levels will climb to the highest level in at least 1 million yrs.

44. Roederer, J. G. (Alaska, University, Fairbanks).
The role of solar-terrestrial research in the international program on global change.
IAF, International Astronautical Congress, 37th, Innsbruck, Austria, Oct. 4-11, 9 p., 1986.

Abstract: The application of solar-terrestrial research (STR) to the International Geosphere-Biosphere program concerned with the study of global change is discussed. The relation between the upper atmosphere and the lower atmosphere and biosphere, and the effect of anthropogenic pollution on the upper atmosphere are examined. STR observational techniques include in situ space and upper atmosphere measurements with spacecraft, rockets, and balloons, in situ ground-based measurements, and remote sensing. The STR data provide information on the variable energy flow from the sun to the earth, its effect on the outer regions of the geosphere, and its interaction with the global earth system. (I. F.).

45. Rosenberg, N. J., et al. (Eds.)
Greenhouse warming: abatement and adaptation.
Washington, D.C.: Resources for the Future, 182p., 1988. (From a workshop, Washington, D.C., June 1988.)

Abstract: Possible impacts of climatic warming and methods of dealing with them are discussed. Several chapters by different authors discuss responses to a rise in sea level, future agricultural adaptations, Third World agriculture, possibilities presented by currently unmanaged forests, and water resource management. One chapter discusses the planting of new forests to sequester carbon dioxide and another is devoted to the use of an economic model to project future carbon dioxide emissions.

46. Sargent, N. E. Canadian Climate Ctr., Atmos. Environ. Serv., Downsview, Canada.
Redistribution of the Canadian boreal forest under a warmed climate.
Climatological Bulletin, Ontario, Canada., 22(3): 23-34, Dec. 1988.

Abstract: A scenario of climate under atmospheric CO^2 levels double those of the present is used to derive a scenario of corresponding changes in the distribution of boreal forest in Canada. Box's model of the response of vegetation to climate is used to obtain more credible results than those obtained by earlier authors by using Holdridge's scheme. It appears that the area climatically suitable for boreal forest would advance by 0.7 MULTIPLIED BY 10 SUPER 8 ha north of its northern edge and retreat 1.7 MULTIPLIED BY 10 SUPER 8 ha north of its southern edge.

47. Schneider, S. H. National Center for Atmospheric Research, Boulder, CO (USA).
The greenhouse effect: science and policy.
Science (Washington, D.C.), 243(4892):771-781, 10 Feb 1989.

Abstract: Global warming from the increase in greenhouse gases has become a major scientific and political issue during the past decade. That infrared radiation is trapped by greenhouse gases and particles in a planetary atmosphere and that the atmospheric CO/sub 2/ level has increased by some 25 percent since 1850 because of fossil fuel combustion and land use (largely deforestation) are not controversial; levels of other trace greenhouse gases such as methane and chlorofluorocarbons have increased by even larger factors. Estimates of present and future effects, however, have significant uncertainties. There have also recently been controversial claims that a global warming signal has been detected. Results from most recent climatic models suggest that global average surface temperatures will increase by some 2 to 6 degrees during the next century, but future changes in greenhouse gas concentrations and feedback processes not properly accounted for in the models could produce greater or smaller increase. Sea level rises of 0.5 to 1.5 metres are typically projected for the next century, but there is a small probability of greater or even negative change. Forecasts of the distribution of variables such as soil moisture or precipitation patterns have even greater uncertainties. Policy responses range from engineering countermeasures to passive adaptation to prevention and a 'law of the atmosphere'. One approach is to implement those policies now that will reduce emissions of greenhouse gases and have additional societal benefits. Whether the uncertainties are large enough to suggest delaying policy responses is not a scientific question per se, but a value judgement. 77 refs., 6 figs., 1 tab.

48. Schneider, S. H.
Global warming: are we entering the greenhouse century?
San Francisco, CA: Sierra Club Books, 317 p., 1989.

Abstract: This book examines, in nontechnical terms, the causes of world-wide climatic change--the "greenhouse effect"--which may raise world temperatures by ten degrees F in less than 100 years. The likely consequences--from agricultural losses and changes in sea level to public health issues and social upheaval--are described. The question of what can be done about the greenhouse effect is addressed as well.

49. Schonwiese, C.-D. Inst. fur Met. und Geophys. der Univ., Frankfurt a./M. **Weltweite Klimaschwankungen: naturlich oder anthropogen? [Worldwide climate fluctuations: natural or anthropogenic?.]**
Naturwissenschaftliche Rundschau, Stuttgart, 38(2): 50-54, Feb. 1985.

Abstract: The problem of whether worldwide climate fluctuations are of anthropogenic or natural origin is examined with particular regard to whether external influences, such as solar activity or volcanic eruptions, have been a cause of the observed temperature fluctuations in the Northern Hemisphere during the past 100 yr. A third important influence that is considered is the increase in atmospheric CO2 of anthropogenic origin. Current knowledge on the increase in atmospheric CO2 , based on the Mauna Loa series beginning with 1958 and some quantitative estimates of the effect of atmospheric CO2 on the temperature, are noted. A review of publications dealing with large-area climatic fluctuations in the course of the measurements of CO2 concentration in the atmosphere, and a review of effects of volcanic eruptions on the course of temperature, particularly in the period 1916-1963, and of attempts and results to establish relationships between the sun-spot number and the solar constant variations and, therefore, climate fluctuations are presented. The author's statistical studies show that the long-term temperature variations in the Northern Hemisphere can be explained to within 80-90% of their variability by the influencing parameters of volcanism, solar constant, and CO2 . Volcanism predominates:

according to the accepted solar influence, volcanism shows a maximum signal of -0.3-0.5°C (minus designates temperature decrease during increasing volcanic activity). Conversely, the solar signal is between 0 and APPROX. 0.3°C with uncertainty, even with regard to sign. The possible effect of the CO2 produced by anthropogenic activity in the Northern Hemisphere ranges between 0.1 and 0.4°C; 0.4°C would indicate that the CO2 effect is already greater than the solar effect. It is concluded that the natural effects on climate fluctuations have been exceeded.

50. Sekihara, K. Met. Res. Inst., Tokyo, Aerological Obs.
Possible climatic changes from carbon dioxide increase in the atmosphere.
In: Bockris, J. O'M. (ed.), Environmental chemistry. N.Y., Plenum Press., p. 285-311, 1977.

Abstract: Current knowledge on the possible role of carbon dioxide increase in the atmosphere in initiating climatic change is reviewed. The contents of this paper include 1) the mixing ratios of the main gaseous atmospheric components causing radiative activity, percentage distribution of various emitting components in the atmospheric downward radiation flux, and solar and terrestrial radiation outside the Earth's atmosphere; 2) the increase of carbon dioxide, as recorded at different sites in the period 1957-1973; 3) the beginning of climatic theory formulating climatic change in terms of CO SUB 2 increase with the work of G. N. Plass in 1966; 4) feedback mechanism and competing causes in modelling climatic change resulting from carbon dioxide increase involving the humidity feedback, the polar ice cap, and aerosols; and 5) the limitations of global average models, such as the Rogers-Walshaw radioactive convective model, the Manabe-Weatherald model, and the general circulation model in the computation of climatic effects by CO2 .

51. Skiba, U.; M. Cresser. Univ. of Aberdeen.
Ecological significance of increasing atmospheric carbon dioxide.
Endeavour, Oxford., 12(3): 143-147, 1988.

Abstract: The impact upon the plant-soil-water ecosystem of the doubling of atmospheric carbon dioxide (CO2) postulated for the next few decades is discussed. In controlled environments, i.e., greenhouses and managed soils, increasing CO2 levels will increase crop yields significantly. In relatively unmanaged environments, such as forests and moorlands, increases in CO SUB 2 may cause long-term problems still needing investigation. Nutrient deficiencies in soils and the acidification of soils and fresh waters may occur, as well as the better known climatic change effects.

52. Tickell, C. Overseas Devel. Admin., London, Eng.
Climatic change and world affairs.
American Geophysical Union, Wash., D.C., EOS: Transactions, 67(17): 425, April 29, 1986.

Abstract: Sooner or later, international rules are needed by which states and communities can establish new and more effective cooperative arrangements and limit the damage to themselves and each other. Such an agreement might fall into three parts. The first part would be designed to cover major experiments by government which might have a climatic impact. The second part would cover actions by governments, such as diversion of ocean currents, blocking or opening of natural waterways, the construction of river dams and irrigation systems above a given size, etc. The third part would set forth a code of good climatic behavior. In this way, the agreement as a whole could be more comprehensive; and as knowledge increased and dangers became more evident, obligations could become more specific and binding.

53. United States Committee for an International Geosphere-Biosphere Program, Washington, DC.
Global change in the geosphere-biosphere: Initial priorities for an IGBP (International Geosphere-Biosphere Program: Final report), DOE/ER/60277-T1, 103 p., 1986.

Abstract: This report outlines the elements of a program that is focused sharply on fundamental problems that have urgent practical implications. These elements define a program that would attempt to understand the workings of the Earth and the living organisms on it as a coupled system - a challenge in science that holds the promise of elucidating many of the global concerns of the present day. It would require the participation of many nations and draw upon the efforts of many fields of science. It would be made up of an array of planned, cooperative programs of observation, modeling, and process studies with organized opportunities for joint discussion and interpretation. It would lean on spaceborne observations for global perspective, but it is not a ''space program,'' for the preponderance of needed science would deal with processes of change, and vast majority of necessary measurements would need be made on the ground and on the oceans, from within the habitat of life. As an international program it would stand as a separate, focused endeavor that interacts with related, disciplinary programs to increase their effectiveness but without attempting to subsume them or to dictate their goals.

54. U. S. Congress. House. Committee on Science and Technology.
International Geosphere/Biosphere program 1984. Hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, US House of Representatives, Ninety-Eighth Congress, Second Session, September 12, 13, 1984.

Abstract: Witnesses at a two-day hearing on the International Geosphere/Biosphere Program for 1984 included US and international researchers in this area and representatives of US departments and agencies connected with interdisciplinary studies of global problems associated with space and the Earth. The witnesses described the program and justified the importance of looking at the earth and atmosphere as a whole, of identifying problems and applying technology to their solution, and of bringing human activity into accord with the natural environment. The program will coordinate measurements that are land-, sea-, and space-based. An appendix with correspondence submitted for the record follows the testimony of the two panels.

55. U. S. Congress. Senate.
S. 2667: A Bill to establish a national energy policy to reduce global warming, and for other purposes. Introduced in the Senate of the United States, One Hundredth Congress, Second Session, July 28, 1988, 150 p., 1988.

Abstract: A bill has been introduced to establish a national energy policy to reduce global warming and other purposes. The bill is entitled the National Energy Policy Act of 1988. The overall purpose of this Act is to establish a national energy policy that will reduce generation of carbon dioxide the trace gases as quickly as is feasible in order to reduce to the maximum extent practicable, risks associated with an atmospheric warming and global climate change. One of the goals of this legislation is to reduce the level of carbon dioxide introduced into the atmosphere by at least 20% by the year 2000.

56. United States Congress. Senate. Committee on Environment and Public Works.
Global warming. Hearing before the Subcommittee on Toxic Substances and Environmental Oversight of the Committee on Environment and Public Works, United States Senate, Ninety-Ninth Congress, First Session, December 10, 1985 S. Hrg. 99-503, 128, 1986.

Abstract: Scientists and public officials testified at a hearing held to explore the evidence and speculation that a warming trend is changing the global environment that was the conclusion of a 29-nation conference of private and government scientists. The witnesses described the potential environmental destruction caused by the greenhouse effect, but also noted that technological solutions in the form of controlling gases and reforestation are available. A consensus has emerged in recent years that gases formed under the greenhouse effect will have a greater effect on climate than any other factor. The witnesses included Ralph Circerone of the National Center for Atmospheric Research, Syukuro Manage of the National Oceanic and Atmospheric Administration, and Carl Sagan of Cornell. Two additional statements submitted for the record follow the testimony of the six witnesses.

57. U. S. Congress. Senate. Committee on Energy and Natural Resources.
National Energy Policy Act of 1988 and global warming. Hearings before the Committee on Energy and Natural Resources, United States Senate, One Hundredth Congress, Second Session on S. 2667, August 11, September 19 and 20, 1988 S. Hrg. 100-923, 546, 1989.

Abstract: Government officials, representatives from EPA, industry, and environmental groups were among those testifying at a hearing on the Federal agencies response to the scientific evidence of global climate change and to receive statements on S. 2667, the National Energy Policy Act of 1988. One of the purposes of this hearing was to underline the administration responsibilities. Various Federal agencies must coordinate their efforts and lead, not stand by and let our climate change while we study the issue. Global atmospheric concentrations of carbon dioxide have been steadily increasing since the advent of the industrial age. During the last 150 years, the level of carbon dioxide in the atmosphere has risen from 280 ppm to 350 ppm. Since 1958, concentrations have increased by about 40 ppm in that short period of time alone.

58. United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C.
Carbon dioxide and climate: summaries of research in FY 1987.
DOE/ER-0347, Oct. 1987,. 95 p. Tables, appendices.

Abstract: This report gives details of programs or projects conducted by various agencies and laboratories in the U.S. during FY 1987 and shows the changes in budget and expenditures from year to year since 1978 when the Dept. of Energy (DOE) was given the role of lead agency in coordinating all government efforts along the line of CO2 climate-related research. The expenditures for fiscal years 1978, 1983, 1984, 1985, 1986, and 1987, and totals for 1978-1987 are categorized by the following work breakdown: energy systems, climate systems, agricultural/ecological systems, resource analysis, scientific interface, integration and evaluation, and program development and management for a total of $ 92 million. The same data are broken down by budgets for university, laboratory, government, industry, and other; with universities handling 42% and national laboratories 40% of the total. Twenty universities in the U.S. and one in England (East Anglia) carry on research projects that are among these projects described in some detail. A great deal of the effort is devoted to modelling. The resulting increase in CO2 in the atmosphere since 1958 is estimated at 17%.

59. United States. National Climate Program Office.
National climate program: five-year plan, 1989-1993.
Rockville, MD: The office, 48 p., 1988. Refs., figs., maps.

Abstract: The primary goal of the program is to understand and predict climatic variations due to natural and anthropogenic factors. Execution of the national climate program will involve government agencies at the federal and state levels, regional organizations, academia and the private sector. During the next five years the following areas will be emphasized: description of the current state of the climate system and influencing factors; determination of current ability to predict climatic change over periods of months to decades; predicting the effect of increased greenhouse gases; assessment of the environmental impact of climatic change due to increased greenhouse gases; and policy analysis.

60. U.S. National Oceanic and Atmospheric Administration. Panel on Climate and Global Change.
The vision: a rededication of NOAA.
Boulder, CO.: University Corporation for Atmospheric Research, 16 p., 1989.

Abstract: The role of NOAA within the U.S. Global Change Program is outlined. NOAA is the natural agency to assume long-term responsibility for obtaining and, in concert with the scientific community, synthesizing authoritative information on global changes in the total environment in a form useful to decision-makers. This responsibility will mean a long-term commitment for operational space observations; in situ measurements; measurement system integrity; processing, analysis, archiving, and quality control of global data sets; oceanic and atmospheric research; maintaining research facilities; and the improvement and validation of climate models. Though well positioned to assume this essential role, NOAA is at present neither adequately equipped nor adequately funded to do it.

61. United States. Oak Ridge National Lab., C. D. Information Center, Oak Ridge, TN.
U.S. Department of Energy Carbon Dioxide Research Division Publications and other documents. Prepared by Martin Marietta Energy Systems, Inc. March 1987.
Abstract: This booklet provides information about the many reports and other materials made available by the U.S. Department of Energy's Carbon Dioxide Research Division (CDRD). It is divided into six sections: research plans and budget summaries; technical reports; workshops, proceedings, and reports; other reports; USDA reports on response of vegetation to carbon dioxide; computer model packages; and numeric data packages.

62. Van der Veen, C. J.
Ice sheets and the CO2 problem.
Surveys in Geophysics, Dordrecht, Holland, 9(1): 1-42, March 1987.

Abstract: The carbon dioxide problem is discussed, with special reference to the possible effects of a global warming on the ice sheets of Greenland and Antarctica. Instead of detailed projections of future climate and the consequences, the basic mechanisms are explained and illustrated with results described in the literature. It is concluded that a doubling of the atmospheric CO2 content (most likely to occur somewhere in the second half of the next century) will result in a globally averaged warming of

2-4°C and an intensification of the hydrologic cycle. In the polar regions, this warming will be a few degrees larger, and, as a consequence, the Greenland Ice Sheet will decrease in size. Antarctica, on the other hand, is expected to grow because of the increased snowfall. The instability of the West Antarctic ice sheet is also discussed, and, although no conclusive prediction to its long-term response can be made, it is argued that, on a short time scale (< APPROX. 100 yr), nothing dramatic will happen to this part of Antarctica.

63. Warrick, R. A. Climatic Res. Unit, Univ. of East Anglia, Norwich.
Carbon dioxide, climatic change, and agriculture.
Geographical Journal, London., 154(2): 221-233, July 1988.

Abstract: Higher ambient levels of carbon dioxide can affect crops directly or indirectly through changes in climate. The results of controlled experiments consistently show that higher carbon dioxide increases dry matter production, largely by stimulating photosynthetic response, decreasing transpiration, and thus improving water use efficiency. Yields of C SUB 3 crops (wheat) could increase by 10-50% for a doubling of carbon dioxide concentrations. The sensitivity of crop yields to changes in climate variables has been investigated through several approaches: crop impact analysis, marginal-spatial analysis, and agricultural systems analysis. Such investigations suggest that, for the core midlatitude cereal regions, an average warming of 2° C may decrease potential yields by 3-17%. Changes in climate at the margins of crop production could result in shifts in the geographic location of potential crop regions, perhaps of the order of several hundred kilometers per °C change in the mid- and high latitudes. Agricultural systems analyses suggest that, to a large extent, the potential adverse effects of climatic change could be absorbed or avoided through agronomic, policy, and market feedback mechanisms. Such results are only tentative. It is not yet possible to predict the combined net effect of both higher CO2 and climatic change on global agriculture.

64. Wigley, T. M. L.; S. C. B. Raper. National Center for Atmospheric Research, Boulder, CO; East Anglia, University, Norwich, England.
Thermal expansion of sea water associated with global warming.
Nature, 330(6144):127-131, Nov. 12, 1987.

Abstract: The relationship between greenhouse-gas forcing, global mean temperature change and sea-level rise due to thermal expansion of the oceans is investigated using upwelling-diffusion and pure diffusion models. The sensitivities of sea-level to short-timescale forcing and deep-water formation rate changes are examined. The greenhouse-gas-induced thermal expansion contribution to sea-level rise between 1880 and 1985 is estimated at 2-5 cm. Projections are made to the year 2025 for different forcing scenarios. For the period 1985-2025 the estimate of greenhouse-gas-induced warming is 0.6-1.0 C. The concomitant oceanic thermal expansion would raise sea level by 4-8 cm. (Author).

65. Woodwell, G. M.
Global warming and what we can do about it.
Amicus J. (United States), p. 8-12, Fall 1986.

Abstract: This paper reviews the greenhouse effect, predictions of future climate, effects on forests and feedbacks to climate change, and the role of deforestation and fossil fuel combustion. It comments on the research program into the greenhouse effect, both in the US and globally. It ends by summarizing the current options for controlling future climate change.

66. World Meteorological Organization.
CAS Group of Rapporteurs on Climate, Final report (Leningrad, 28 October-1 November 1985).
Its World Climate Research Programme WCRP-7, 17 p. (WMO/TD No. 226), April 1988.

Abstract: This document reports on the results of the activities of the CAS related to the World Climate Research Program: 1) decisions and recommendations of CG-IX and EC sessions, JSC-V1, and advisory Working Group-V11: 2) future activities of CAS with regard to tropical meteorology, WMO projects on atmospheric gases and pollutants, baseline radiation stations, sea ice, and atmospheric radiation; 3) active projects in support of specific aspects of climate research, including intercomParison of parameterization codes and other studies for boundary layer processes, interactions between the stratosphere and troposphere in modelling tropospheric climate, climate diagnostics, aerosol monitoring and aerosol climatologies, and relation between ICSU program on global change (ICSU/PGC) and the WRCP; and 4) reestablishment of the CAS group on climate. A paper on the role of the stratosphere in modelling tropospheric climate is included as an appendix.

67. World Meteorological Organization. World Climate Program, Geneva.
Guidelines on the structure, management, and operation of climate data centres. Prepared by the Inter-Commission Meeting on Climate Data Centre Design and Operations, Atmospheric Environment Service, Downsview, Ontario, Canada, Oct. 29-Nov. 2, 1984.
Its WCP-99, [1985]. 28 p. text. Appendices separately paged. (WMO/TD No. 48).

Abstract: The purpose of a Climate Data Center, the definition of small, medium, and large climate data centers, and general user requirements are summarized. The following features of climate data centers are then described; 1) the function and structure of such centers; 2) data collection and communications; 3) quality control and processing; 4) structure of the climate center base: manuscript, microfilm/microfiche, digital archives, intial startup of a climate data center, and archival of remote sensing data; 5) management of the digital climate center data base; 6) data center outputs/products; 7) data security; and 8) staff requirements, characteristics and organizations, computer hardware and software, etc.

68. Wuebbles, D. J.; J. Edmonds. Lawrence Livermore Natl. Lab., CA.; Pacific Northwest Lab., Wash., D.C.
Primer on greenhouse gases.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Science, Wash., D.C., DOE/NBB- 0083, 100 p., March 1988.

Abstract: This document provides a reference summarizing current understanding of basic information for gases considered to be important to the future state of global atmospheric chemistry and climate. The greenhouse gases included are CO2 , O SUB 3 , CH SUB 4 , N2O, CFCl SUB 3 , CF SUB 2 Cl SUB 2 , CO, NO SUB x , brominated hydrocarbons, CO, SO SUB 2 , and COS; they are those of direct radiative importance to climate, those acting as radiative precursors, and those of importance as intermediate constituents because of their chemical activities. For each of the gases, the following information is given: trace gas classical formula; sources; percent of total sources related to energy; sinks; current concentrations; atmospheric lifetimes; current atmospheric trends; whether radiatively or chemically interactive; direct chemical effects; direct climate effects; index of radiative sensitivity compared to CO2 ; chemical-climate interactions; uncertainties in basic chemistry; uncertainties in applied chemistry; and uncertainties in radiative transfer. The material is presented in the form of an extended table.

Monitoring Global Climate Change

1. Angell, J. K. Air Resources Lab., ERL/NOAA, Silver Spring, MD.
Variations and trends in tropospheric and stratospheric global temperatures, 1958-87.
Journal of Climate, Boston., 1(12): 1296-1313, Dec. 1988.

Abstract: Examined in this paper are the variations and trends in tropospheric and low-stratospheric temperature for seven climatic zones, hemispheres, and the world for intervals 1958-1987 and 1973-1987, based on 63 well-distributed radiosonde stations. For the 30-yr interval 1957-1987, these data indicate an increase in year-average global temperature at the surface and in the tropospheric 850-300-mb layer of 0.08°C (10 yr) SUPER - SUPER 1 and 0.09°C (10 yr) SUPER - SUPER 1 , respectively, just significant at the 5% level. Nevertheless, during this interval, there is evidence for a slight decrease in year-average temperature at the surface and in the troposphere of the north polar and north temperate zones. The global 300-100-mb temperature is indicated as having decreased by 0.18°C (10 yr) SUPER - SUPER 1 during this 30-yr interval (significant at the 1% level), with a temperature decrease in all seven climatic zones, although largest in the south polar zone (associated with the Antarctic ozone hole phenomenon). For the 15-yr interval 1973-1987, the global temperature in the low stratospheric 100-50-mb layer is indicated as having decreased by a significant 0.62°C (10 yr) SUPER - SUPER 1 , the decrease again largest in the south polar zone 2.04°C (10 yr) SUPER - SUPER 1 , but observed in all zones except the north temperate zone. During 1958-1987, there is evidence for an increase in the meridional temperature gradient between the equatorial zone and north polar zone both at the surface and in the troposphere, but in the Southern Hemisphere, there has been a decrease in this gradient at the surface and essentially no change in the troposphere. In the hemispheric and global average, warming has been greater (though not significantly so) in MAM (March-April-May) and JJA than in DJF and SON, both at the surface and in the troposphere, although in both polar zones the surface warming has been greatest in winter. The close relation between sea surface temperature in the eastern equatorial Pacific and tropospheric temperature in the Tropics is discussed in some detail. Finally, temperature variations and trends in the Western Hemisphere tropics are examined to heights of 55 km by using high-level radiosonde and rocketsonde data.

2.
Antarctic lakes: indicators of global climate change?
Antarctic, Journal of the United States, Wash., D.C., 22(4): 11-13, Dec 1987.

Abstract: Scientists agree that changes in the ice sheets of East and West Antarctica could indicate changes in the Earth's climate. Now, data from a 10-yr study suggest that Antarctica may hold another means by which observers can judge the stability of the global climate-the small lakes that pepper the ice-free regions of the continent. Biologists working in these ice-free or dry valleys in southern Victoria Land conclude from their research that the lakes may record short-term (periods of <100 yr) alterations in the climate.

3.
U.S. scientists continue ozone depletion studies during the 1987-1988 austral summer.
Antarctic, Journal of the United States, Wash., D.C., 22(3): 1-4, Sept 1987.

Abstract: Working at Palmer Station and along the Antarctic Peninsula aboard the R/V Polar Duke, two teams of marine biologists measured how the increased exposure to UV light affects the Antarctic marine ecosystem. The projects are part of the U.S. study of the annual spring depletion of ozone over Antarctica and the effects of decreased ozone levels on the environment. Data show that, starting in 1979, a dramatic decrease in stratospheric ozone over the southern continent occurred each austral spring. In late Aug. or early Sept., a hole approximately the size of the U.S. begins to form; the decline continues through Sept. and Oct., with a recovery during Nov. The eight projects of the National Ozone Expedition are among the 69 that the National Science Foundation has funded for the 1987-1988 austral summer Antarctic program.

4. Barnett, T. P. Scripps Inst. of Ocean., Univ. of CA., San Diego.
Detection of changes in the global troposphere temperature field induced by greenhouse gases.
Journal of Geophysical Research, Wash., D.C., 91(D6): 6659-6667, May 20, 1986. Refs., figs.

Abstract: Several approaches to detecting the existence of a theoretically predicted CO2 -induced signal in the global temperature field are investigated. It appears that a relatively thin network of observing stations can, when properly analyzed, provide a first-order estimate of global-scale temperature change and that this measurement is not necessarily the global average temperature. By using these stations, it is possible to estimate the strength of an a priori CO2 signal in the three-dimensional tropospheric temperature field. This signal is derived from two different general circulation model simulations, both with some form of interactive oceans. The observed signal strength over 1960-1980 is APPROX. 0.5-1.0 times that expected theoretically. The observed signal demonstrated a trend that is marginally significant.

5. Barnett, T. P. Scripps Inst. of Ocean., La Jolla, CA.
Long-term climate change in observed physical properties of the oceans.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0235, p. 91-107, Dec. 1985. Refs., figs.,

Abstract: Changes in the key ocean variables of sea surface temperature, sea level, and salinity over space and time, with the aim of using the available data to detect possible CO2 -induced changes and their time variability over decades are discussed. Spatial and temporal changes in density and changes in the general circulation of the oceans are also examined. The importance of the variations of these factors, the measurement methods, and data quality and distributions are surveyed. Recent analysis and variations of relative sea level, including the roles of ice melt, temperature change, and circulation change, are reviewed. The recent analyses and variations of surface air temperature, marine air temperature, and surface sea temperature and their interrelations, and of subsurface temperature are summarized. The recent analyses and variations of salinity and density are summarized. Analyses of existing limited data suggest changes in relative sea level of 10-25 cm per century along many, but not all, of the continental margins.

Furthermore, small- scale features (eddies, internal waves) in the oceans introduce such high noise levels in attempts to study oceanwide changes in temperature, salinity, and density that inferred trends over the last 50 yr are generally a factor of 10 less than the uncertainty of their estimates.

6. Barry, R. G. Univ. of CO., Boulder.
Cryosphere and climate change.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOR/ER- 0235, p. 109-148, Dec. 1985. Refs., figs. tables.

Abstract: A comprehensive overview of the relationship between the cryosphere and climate change is presented. The snow and ice components (area, ice volume, and level equivalent changes) are presented in a table. The role of the cryosphere in the climate system, and climate and cryosphere-climate interactions involving long- term changes in atmospheric CO2 content are summarized with regard to the elements of the cryosphere, snow cover, sea ice, freshwater ice, ground ice, permafrost and glaciers, and ice sheets. Their significance, the observations, the space-time coverage of the data, and the interactions of the individual cryospheric elements with climate are discussed.

7. Bolle, H.-J.; W. Seiler; B. and Bolin. Inst. fur Met. und Geophys., Univ. Innsbruck, Austria; Max-Planck-Inst. fur Chemie, Otto Hahn Inst., Mainz, W. Germany; Dept. of Met., Arrhenius Lab., Univ. of Stockholm, Sweden.
Other greenhouse gases and aerosols: assessing their role for atmospheric radiative transfer.
In: Greenhouse Effect, Climatic Change, and Ecosystems. Chichester, Eng., John Wiley & Sons, p. 157-203, 1986.

Abstract: A comprehensive review of the current state of knowledge on the direct radiative effects of atmospheric gases other than CO2 and on aerosols in the atmosphere is presented. The following topics are discussed: 1) trace gases in the atmosphere, including the role of trace gases in climatic studies and past and present concentrations of methane, its sources and sinks and their temporal changes, and long-term trends; 2) past and present concentrations of nitrous oxide, its sources and sinks and their temporal changes, and interaction of N20 with other atmospheric trace gases; 3) past and present concentrations of chlorofluorocarbons (CFCs), and ozone (formation and destruction, tropospheric and stratospheric ozone, and total ozone); 4) probable future concentrations of atmospheric greenhouse gases, guide lines for estimation of probable future concentrations, and estimates of methane, chlorofluorocarbons (CFCL SUB 3 , CF SUB 2 CL SUB 2), nitrous oxide, and ozone; 5) radiative effects of greenhouse gases, including some principal considerations, model computations and the importance of spectral overlapping, and climatic effects of projected increases of other greenhouse gas concentrations; and 6) aerosols, including aerosol type and variability, radiative effects, and possible future changes of climate resulting from anthropogenic aerosols.

8. Gates, W. L.; M. C. MacCracken. Climatic Res. Inst., OR. State Univ.; Lawrence Livermore Natl. Lab., CA.
Challenge of detecting climate change induced by increasing carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0235, p. 1-12, Dec. 1985. Refs.,

Abstract: The framework providing a basis for efforts to detect the climatic effects of increasing CO2 concentrations in the atmosphere is discussed. A review of the characteristics of climate and of some of the factors that may play a role in inducing climatic change is presented, and the following are considered: definition of climate and climate change; factors controlling the climate, including both external and internal forcing factors; and the baseline climate (climate over the last 10 SUPER 4 -10 SUPER 5 yr and 10 SUPER 2 -10 SUPER 4 yr). A description is given of methods for determining whether climate is changing currently (or has changed in the past). Detection and the observational record, detection and the understanding of climate change, and climate models and identification of the CO SUB 2 signal are discussed.

9. Gavrilova, M. K. Inst. Merzlotovedeniya SO, Akad. Nauk, U.S.S.R.
Predpolagayemyye izmeneniya klimata i vozmozhnaya dinamika vechnoy merzloty. [Expected climate changes and possible dynamics of permafrost.]
Meteorologiya i Gidrologiya, Moscow, No. 7, p. 114-116, July 1984. Transl. into English in corresponding issue of Meteorology and Hydrology, Wash., D.C. Available from NTIS, Springfield, VA. 22161.

Abstract: The influence of possible anthropogenic climate changes on the freezing and thawing regimes of soils and the phenomena of permafrost are examined. Intended and united regional-local, micro-, and nanoeffects on climate, as well as effects of a microclimatic character, associated with the expected warming in the coming century are investigated. Data from the published literature and those obtained by the author on estimates of climatic warming in the 20th century globally, particularly in Western and Eastern Siberia and the Far East, are cited with particular regard to effects on permafrost. It is concluded that, if in the middle of the 21st century, the climate will warm intensely, a transformation in the permafrost regime of the soils is to be expected. Permafrost rocks in the near-surface layer are preserved mainly in mountain regions and high latitudes of the Arctic (the Taimyr Island and peninsulas) with a general rise in soil temperature. In the remaining regions, there is intense thawing of the bottom soils and a rise of temperature in the upper layers. However, as a result of the thermal processes in frozen rocks, this occurs only within the limits of annual temperature fluctuations (5-15 m). Hence, islands of frozen rocks of not very great thickness may disappear. Over a large part of the permafrost region, permafrost may survive as a relict phenomenon.

10. Gorshkov, V. G.
Rol' okeana v pogloshchenii antropogennykh vybrosov CO2 iz atmosfery. [Role of the ocean in the absorption of anthropogenic CO SUB 2 rejection from the atmosphere.]
Vsesoyuznoye Geograficheskoye Obshchestvo, Leningrad, Izvestiya, 118(5): 386-395, Sept./Oct. 1986. Refs. Russian summary.

Abstract: Different approaches for determining the absorption capacity of the ocean are examined. On the basis of a review of the published literature, numerical values are obtained for the absorption of atmospheric CO2 by the ocean through the air-sea surface; the physical-chemical absorption of CO2 by the ocean; the biogenic absorption of CO2 by the ocean; and the distribution of differences of CO2 concentration in the ocean. It is shown that the rate of pure absorption CO2 by the ocean from the atmosphere is proportional to the increment of the mass of CO2 in the atmosphere in comParison with the preindustrial steady-state level. The magnitude of absorption is determined by the biological processes in the ocean. The rate of biological absorption by the ocean exceeds, by an order of magnitude, the pure physical-chemical absorption by the ocean.

11. Halter, B. C.; J. T. Peterson. Cooperative Inst. for Res. in Environ. Sci., Univ. of CO., Boulder; Air Resources Labs., NOAA, Boulder.
On the variability of atmospheric carbon dioxide concentration at Barrow, Alaska, during summer.
Atmospheric Environment, Oxford, 15(8): 1391-1399, 1981. Refs., figs. (Special Issue: Arctic Air Chemistry).

Abstract: Atmospheric carbon dioxide data obtained at Barrow, Alaska, for the May-September period of 1978 were studied to understand the causes of the day-to-day and within-day variations. Sixteen instances of 24-hr change in average CO2 concentration of 15-50% of the annual range (APPROX. 14 p.p.m.) were identified. Within-day variations of as much as 50% of the annual range were noted. The variations were found to be related to local- and synoptic-scale meteorology interacting with local Barrow CO2 record which can be used in the selection of representative data for studying large-scale trends.

12. Hatch, D. J.
Distribution of world climate conditions.
Journal of Meteorology, Trowbridge, Eng., 13(133): 344-349, Nov. 1988.

Abstract: The author compiled standardized climatic data for 500 places in all the regions of the world, highlighting those locations where extreme conditions occur (Weather around the World, Oct. 1984). In addition to monthly, seasonal, and annual data of temperatures, rainfall, sunshine, and wind speed for these places, listings and maps were provided of the principal elements of climate. Additional features were the calculations of wind chill, of discomfort caused by a combination of heat and humidity, and of an overall climate code which, although subjective in nature, attempted to combine the individual elements of climate at each place into a single, comparable index of climate value. This article illustrates some of the results of these analyses. The climate information refers to average weather, where considerable extremes of temperature or rainfall occur, these will be reflected only in as far as they affect average values. This may have a marked effect upon the interpretation of the climate code, described below, where a near idyllic climate may be rendered far from attractive by occasional destructive tropical cyclones, smog, periods of extreme heat or cold, or high humidity, etc. The value of the information is limited by the quantity and quality of the source data. Unfortunately, the available data are sadly lacking, far from standardized, out of date, and often numerically inaccurate. The data of the U.S. National Climatic Data Center may be singled out for praise in this context-accurate, up-to-date information readily available at minimal cost. Unfortunately still published in nonmetric units, converted they form the basis for the data on places in the U.S. presented here. Other sources used, both primary and secondary, and updated, converted, or corrected where necessary, are the following: HMSO Tables of Temperature, Relative Humidity, and Precipitation for the World, various dates; M. Muller, Handbuch ausgewahlter Klimastationen der Erde, 1980; Pearce and Smith, The World Weather Guide, 1984; and World Meteorological Organization, Climatological Normals 1931-1960, 1971. For many stations, the period upon which the data are based is limited, which may mean that extreme values are understated. The maps do not pretend to give more than a generalized global picture of the distribution of the elements covered. Local topography, in particular mountains, or the influence of the oceans will clearly lead, in many cases, to significant deviations from global values. For certain elements, rankings are given of values for the highest and lowest 50 stations. In the case of the climate code, no data are available for APPROX. 100 stations because basic data on sunshine hours are lacking.

13. Hattemer-Frey, H. A.; T. R. Karl; F. T. Quinlan. Carbon Dioxide Information Ctr., Oak Ridge Natl. Lab., TN.; Natl. Climatic Data Ctr., Asheville, N.C.
Annotated inventory of climatic indices and data sets.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/NBB- 0080, 195 p., Nov. 1986.

Abstract: This publication describes 34 prominent climatic indices and provides an annotated listing and bibliography of additional indices to meet the information needs of researchers who are evaluating the effects of increased CO2 levels. The indices are grouped into 10 subject areas: 1) global/hemispheric data sets (monitoring a climatic variable for one or both hemispheres): Northern Hemisphere surface air temperature, Russian surface air temperatures, and Southern Hemisphere surface air temperatures; 2) marine data sets: comprehensive ocean-atmosphere data sets (COADS), global sea level changes, nighttime near-surface marine air temperatures, and tide-gage measurement of global sea level changes; 3) global and local long-term temperature and precipitation data sets: Arctic, Arctic regions, and Antarctic surface air temperatures; central England temperatures; dryness/wetness index for China; England, and Wales precipitation; Indian monsoon rainfall record and drought area indices; New Zealand temperature and precipitation record; rainfall series for four sub-Saharan zones; sub-Saharan rainfall index; and U.S. temperature and precipitation record and drought area index; 4) atmospheric constituents data sets: aircraft measurements of atmospheric CO2 concentrations over the Australian region; atmospheric CO2 variations at Mauna Loa Observatory, Hawaii, and the South Pole; dust veil index; and mean annual stratospheric aerosol optical depths estimates; 5) upper air data sets: circulation patterns and world climate, trade wind field over the Pacific Ocean, and tropospheric and stratospheric temperatures; 6) Southern Oscillation/El Nino data sets: atmospheric characteristics associated with the Southern Oscillation, persistence and interannual variability of the Southern Oscillation, and Southern Oscillation indices; 7) solar data sets: umbra/penumbra ratio, and Zurich (Wolf) sun-spot numbers; 8) Proxy data sets: 22-yr cycle in drought area indices for the western U.S.; past volcanic activity determined from Greenland ice cores; reconstructed estimates of temperature, sea level pressure, and Southern Oscillation index values; and reconstructed Northern Hemisphere temperatures; 9) lake level and river flow data sets: changes in the level of three East African lakes; and 10) snow cover and sea ice extent data sets: changes in snow cover and sea ice and the reflection loss index for the Northern Hemisphere. Additional climatic indices are listed in the appendix; and an extensive bibliography is included. For each of the 34 climatic indices, the following information is given: the primary reference, the application, the background, the calculation, the temporal and spatial resolutions, the units, the period of record, the reliability, the manner in which the index compares with other indices, the sponsor of the index, and the number of times the primary reference has been cited since published.

14. Intergovernmental Oceanographic Commission, Paris.
Ocean observing system development programme: a World Climate Research Programme action plan.
Sponsored by WMO, International Council of Scientific Unions, Scientific Committee on Oceanic Research, and the Intergovernmental Oceanographic Commission. Its Technical series, No. 27, 31 p., 1984.

Abstract: This report describes the principles that govern the Ocean Observing System Development Program (OOSDP) for the three streams of the World Climate Research Program (WCRP): 1) the physical basis for long-range prediction of weather anomalies; 2) interannual variability of global atmospheric climate and the tropical oceans; and 3) long-term variations and the sensitivity of the climate system to external influences. A survey is made of the objectives of the OOSDP, the unique features of this program and its underlying

assumptions, and the requirements for each of the streams of WCRP. General issues combined with the variables to be observed or derived are reviewed, i.e., overlap of historical and new (mainly satellite) technology, error analyses, data management systems, and the relationship between research and operational observing programs. The variables investigated are sea surface temperature, mean sea level, surface stress, subsurface heat storage, sea ice, surface heat flux, and ocean currents. WCRP requirements, scientific background, various aspects of data analysis, data collection, and management of the operations (both scientific and technological) are discussed for each of these variables. A program that uses satellite-tracked surface drifters to meet data requirements is described. A list of the major programs is presented.

15. International Geographical Union Global Database Planning Project, 1st, Hampshire, Eng., May 9-13, 1988.
Building databases for global science: Proceedings. Published by Taylor and Francis., 1988.

Abstract: This publication contains the papers presented at the first meeting of the International Geographical Union's Global Database Planning Project, which was convened to examine the provision of databases to the International Geosphere Biosphere Program and which was held May 9-13, 1988. The papers deal with 1) various aspects of global database design and the issues inherent in such design: accuracy selection of appropriate data models for global databases, cartographic data inputs to global databases, integration of remote sensing and geographic information systems, etc.; and 2) applications of world database systems, including the World Data Center system, international exchange and global change; methodology for multisatellite mapping; a CODATA program on remote sensing in earth science; world digital database for environmental sciences (WDDES); the role of the World Meteorological Organization in developing countries; global databases; a NOAA experience; activities associated with global databases in NASA; the IOC ocean-mapping activities; etc.

16. Kondrat'yev, K. Y.; M. A. Prokof'yev; D. V. Pozdnyakov. Inst. for Lake Studies of the Acad. of Sci., Leningrad.
Aerosol properties and their significance for climate studies.
Idojaras, Budapest, 89(2): 57-69, March/April 1985. Refs. English and Hungarian summaries.

Abstract: The authors review typical aerosol properties and possibilities for typifying atmospheric aerosols with regard to the need for information on aerosol properties for climate modelling. Principal problems of studying aerosol cimatic impact are considered. A general picture of sources, sinks, and dynamics of global aerosols is given. Preliminary atmospheric aerosol models are described.

17. Lachenbruch, A. H.; B. V. Marshall. Off. of Earthquakes, Volcanoes, and Engr., U.S. Geol. Survey, MenloPark, CA.
Changing climate: geothermal evidence from permafrost in the Alaskan Arctic. Science, Wash., D.C., 234(4777): 689-696, Nov. 7, 1986. Refs., figs.

Abstract: Temperature profiles measured in permafrost in northernmost Alaska usually have anomalous curvature in the upper APPROX. 100 m. When analyzed by heat conduction theory, the profiles indicate a variable, but widespread, secular warming of the permafrost surface, generally in the range of 2-4°C during the last few decades to a century. Although details of the climatic change cannot be resolved with existing data, there is little doubt of its general magnitude and timing; alternative explanations are limited by the fact that heat transfer in cold permafrost is exclusively by conduction. Because models of greenhouse warming predict climatic change will be greatest in the Arctic and might already be in progress, it is prudent to attempt to understand the rapidly changing thermal regime in this region.

18. Lal, D.; W. Berger. Scripps Inst. of Ocean., La Jolla, CA.
Global environmental change and the ocean.
In: Malone, Thomas F.; Roederer, Juan G. (eds.), Global Change. Cambridge, Eng.: Cambridge University Press, 1985. p. 157-170. (ICSU Press Symposium Series No. 5).

Abstract: As a result of extensive physical, chemical, biological, meteorological, and geophysical studies in the past decades, the dominating role of oceans in controlling the global environment on time scales of decades to centuries has become manifest. The data sets indicate the necessity of observing oceans on a wide range of space and time scales with sufficiently high resolution to understand the ocean-atmosphere phenomena. The authors outline important oceanic processes that must be well understood and make recommendations for the observations that must be made to fulfill the objectives and goals of this International Geosphere- Biosphere Program.

19. MacCracken, M. C.; F. M. (eds.) Luther. Lawrence Livermore Natl. Lab., Livermore, CA.
Detecting the climatic effects of increasing carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0235, Dec. 1985. 198 p. Refs., figs., Tables. Available from NTIS, Springfield, Va. 22161

Abstract: This publication is part of a series of state-of-the-art volumes reviewing the current state of scientific understanding on the potential effects of the increasing CO2 concentration in the atmosphere. It contains chapters dealing with methods and results of detecting the changes in climate caused by the increase in atmospheric concentration of CO2 and isolating these changes from those caused by other natural or anthropogenic factors. Individual chapters written by different authors deal with problems of detecting climatic change induced by increasing atmospheric CO2 , determination of the radiative signal of increasing CO2 and other trace gases, analysis of the temperature record, long-term climate change in observed physical properties of the ocean, the cryosphere and climatic change, and long-term changes in precipitation. A chapter summarizing the aforementioned chapters is included. Each chapter contains an extensive list of references.

20. Peterson, J. T. Geophys. Monitoring for Climatic Change, NOAA, Boulder, CO. **Atmospheric CO2 variations at Barrow, Alaska, 1973-1982.** Journal of Atmospheric Chemistry, Dordrecht, Holland, 4(4): 491-510, Dec. 1986. refs., figs

Abstract: The first 10 yr (1973-1982) of atmospheric CO2 measurements at Barrow, Alaska, by the NOAA/GMCC program are described. The paper updates and extends the Barrow CO2 record presented in Tellus (1982). The data are given in final form, based on recent calibrations of the Scripps Institution of Oceanography, with selected values identified as representative of large, space-scale conditions. Analyses of the data show: 1) a long-term CO2 average increase of 1.3 p.p.m./yr, but with large, year-to-year variations in that growth rate; 2) a suggestion, not statistically significant, of a secular increase in the amplitude of the annual cycle, presumably a reflection of global-scale biospheric variability; and 3) good absolute agreement between the Barrow results and those from four neighboring high-latitude sites between 50 and 82°N.

21. Peterson, J. T.; W. D. Komhyr. Geophys. Monitoring for Climatic Change, Air Resources Lab./NOAA,Boulder, CO.
Atmospheric CO2 measurements at Barrow, Alaska.
World Meteorological Organization, Geneva, Special Environmental Report No. 16, 1985. p. 76-80. Refs. (WMO-No. 647).

Abstract: Preliminary results of the measurement of atmosphere CO2 performed at Point Barrow, Alaska, for the period 1973-1982 as part of the U.S. Geophysical Monitoring for Climate Change (GMCC) program are presented. The CO2 data set was obtained from a continuously operating in situ nondispersive IR analyzer and by simultaneously collecting air samples in 0.5-1 glass flasks for a subsequent analysis. Graphs and a table are presented giving the monthly average concentration at Barrow, Alaska, and Mauna Loa, Hawaii for 1973-1982; annual mean concentrations at Barrow and year-to-year changes; and NOAA CO2 flask data at Barrow for 1971-1982. The Barrow record is characterized by large-amplitude cycles and long-term increase and by a change in the year-to-year growth rate of mean CO2 concentration over the entire period. The flask record clearly shows the annual record and long-term trend.

22. Ramanathan, V. Natl. Ctr. for Atmos. Res., Boulder, CO.
Role of Earth radiation budget studies in climate and general circulation research.
Journal of Geophysical Research, Wash., D.C., 92(D4): 4075-4095, April 20, 1987. Refs., figs.

Abstract: Two decades of nearly-continuous measurements of Earth radiation budget data from satellites have made significant contributions to the understanding of the global mean climate, the greenhouse effect, the meridional radiative heating that drives the general circulation, the influence of radiative heating on regional climate, and climate feedback processes. The remaining outstanding problems largely concern the role of clouds in governing climate, in influencing the general circulation, and in determining the sensitivity of climate to external perturbations, i.e., the cloud feedback problem. A remarkably simple and effective approach is proposed to address these problems, with the aid of the comprehensive radiation budget data collected by the Earth Radiation Budget Experiment (ERBE). ERBE is a multisatellite experiment that began collecting data in Nov. 1984. The simple approach calls for the estimation of clear-sky fluxes from the high spatial resolution scanner measurements. A cloud-radiative forcing (or simply cloud forcing) is defined, which is the difference between clear-sky and cloudy-sky (clear plus overcast skies) fluxes. The global average of the sum of the solar and long-wave cloud forcing yields directly the net radiative effect (i.e., cooling or warming) of clouds on climate. Analyses of variations in clear-sky fluxes and the cloud forcing in terms of temperature variations would yield the radiation temperature feedbacks, including the mysterious cloud feedback, which are needed to verify present theories of climate. General circulation model results are used to discuss the nature of the cloud radiative forcing. It is shown that the long-wave effect of clouds is to enhance the meridional heating gradient in the troposphere, whereas the albedo or solar effect of clouds is largely to reduce the available solar energy at the surface. The long-wave cloud-induced drive for the circulation is particularly large in the monsoon regions. Thus, it is concluded that analyses of ERBE data in terms of cloud forcing would add much needed insights into the role of clouds in the general circulation. With regard to the future, the scientific need is discussed for continuing broadband measurements of Earth radiation budget data into the next century to understand the processes that govern interannual and decadal climate trends. The spectral variations in clear-sky fluxes and cloud forcing and the need for broadband data to obtain the desired accuracies are described.

23. Reiter, R.; H. Jager. Fraunhofer Inst. fur Atmos. Umweltforschung, Garmisch-Partenkirchen, E. Germany.
Results of 8-year continuous measurements of aerosol profiles in the stratosphere with discussion of the importance of stratospheric aerosols to an estimate of effects on the global climate.
Meteorology and Atmospheric Physics, Vienna, 35(1/2): 19-48, 1986. Refs., figs. English and German summaries.

Abstract: After a short description of the measuring technique used, the results of an efficient lidar system to determine stratospheric aerosol profiles to 30 km are reported in detail. Technical data of the lidar system are: 100-MW transmitter energy, 20-nsec pulse length, 1-sec pulse repetition, 694-nm wavelength, single photon counting with the use of a chopper for suppressing fluorescence of the laser crystal after the shot, fully automated control of the measuring procedure, and storage of data by computer. Shown as examples are the first individual profiles of the stratospheric aerosol distribution after the most violent eruption of the recent past (El Chichon, 1982). These profiles reveal the rapid variations of the profile structure caused by the different flow conditions as a function of season. The results make clear that the fastest possible sequence of lidar measurements is required to obtain significant and application-oriented data. The integrated backscattering is presented from the beginning of 1977 to the end of 1984. Its variations, resulting from a whole series of volcanic events during the period, are discussed in comParison with the background conditions of 1977-1978. The residence time of stratospheric aerosols is derived for different layers of the stratosphere with an estimate of the mean residence time of particles <0.5- MU m diameter at the respective level. The dramatic variation of the stratospheric aerosol distribution at 47°N lat. shortly before and immediately after the El Chichon eruption and continuously until summer 1984 is shown with three-dimensional diagrams. The different temporal trends in the behavior of the stratospheric aerosol in midlatitudes as a function of the latitude of volcanic eruptions are discussed with examples. The results of measurements are compared with those of other groups. Calculations of the optical depth are shown from early 1982 to late 1984 and are compared with background conditions from 1978. The stratospheric aerosol mass in the column above the unit surface is graphically plotted as a function of time. In several passages, it is pointed out that not only El Chichon, as the last extreme volcanic event, must be considered but also minor volcanic eruptions that occurred in different countries in late summer and fall 1983. An overview is given of the available literature concerning the question of an impact on climate, especially on the Northern Hemisphere temperature by stratospheric turbidity; and conclusions are drawn as to the practical application of the measurement results. On the basis of reliable data from the literature, a volcanically induced cooling of APPROX. 0.5 K is to be expected from 1984-1985 on, followed by a gradual normalization (provided that no new major volcanic eruptions occur).

24. Rowland, F. S.; D. R. Blake; E. W. Mayer. Dept. of Chem., Univ. of CA., Irvine.
Worldwide increase in concentration of atmospheric methane since 1978.
World Meteorological Organization, Geneva, Special Environmental Report No. 16, 1985. p. 33-46. Refs. (WMO-No. 647).

Abstract: Methane is the most abundant carbon-containing species in the atmosphere next to fully oxidized carbon dioxide, and is largely the product of biological activity in anaerobic environments. In this study, experiments to determine the CH SUB 4 concentrations in two extensive series of ground-level air samples taken during two separate time intervals in 1983 in remote locations between 71°N and 47°S lat are described. The overall world average for these tropospheric samples indicates an increase of APPROX. 0.06 p.p.m.v. in atmospheric methane over the 3-yr period from 1980-1983 and APPROX. 0.10 p.p.m.v. for 1978-1983. This world trend is consistent with APPROX. 0.02 p.p.m.v. increase per year anywhere. On the basis of a review of various studies, the seasonal variations of methane; the greenhouse effect from methane; the source strength of HO radicals which, by reaction with CH SUB 4 , provide the only important process for removing methane from the troposphere; the demand for oxidation by the HO radical reaction in the troposphere; sources of methane emission; and tonnage of atmospheric methane are discussed.

25. Schonwiese, C.-D.
Kohlendioxid (CO2). [Carbon dioxide (CO2).]
Promet: Meteorologische Fortbildung, Offenbach a./M., 15(4):2-5, 1985.

Abstract: This paper reviews the history of the accumulation of data on the concentration of CO SUB 2 in the atmosphere, and on its significance in the temperature regime of the atmosphere. The heating effect of CO2 upon the atmosphere has already been noted by Fourier (1827) and Arrhenius (1896) and, in 1938, Callender published a paper on the artificial production of CO SUB 2 and its influence on temperature. Serious and systematic study of the CO2 role in atmospheric temperature began with the publication of a paper by Plass (1956) on the CO2 theory of climate. This paper reviews the physical basis of the CO2 effect upon climate, involving the IR absorption of CO SUB 2 ; measurements of atmospheric concentration of atmospheric CO2 conducted since 1958 at different stations; and the march of the CO2 concentration over this period: the mean (1975-1982) march of CO2 at Mauna Loa, Point Barrow (Alaska), and the South Pole; annual amplitudes of CO2 concentration on Mauna Loa; the fluctuations of atmospheric CO2 concentration during the past 40 MULTIPLIED BY 10 SUPER 3 yr; and indirect determinations of atmospheric CO2 concentration as obtained from ice cases. The relationship of the atmospheric CO2 concentration to climate variation is evaluated.

26. Simon, K.
Neue Zahlen zu CO2 und Klima. [New numbers on CO2 and climate.]
Naturwissenschaftliche Rundschau, Stuttgart, 37(7): 294-295, July 1984.

Abstract: On the basis of recent publications, some of the latest estimates of atmospheric CO2 concentrations to the year 2100, in the geological past and in historical periods, are summarized. Various estimates propose that the annual increase of CO2 is 1-3.5% and that at a value of 2%, the amount of atmospheric CO2 will double in 88 yr. The National Research Council predicts a fourfold increase in CO2 by the year 2100. Ice cores obtained in the Greenland ice indicate a CO2 concentration of 0.29 per thousand before the industrial period. A CO2 concentration of 0.27 per thousand was found in Antarctic ice 1000 yr old. Investigations of the C-13/C-12 ratio in plants millions of years old indicate a preindustrial concentration of 0.26%. On the Pacific Coast, a concentration of 0.276% was determined as compared with a current concentration of 0.34%. A comParison of the oxygen and nutrients content of the North Atlantic between 1972 and 1981 revealed no change, through a gradual rise in CO2 absorption of the world ocean. Investigation of cores of very old ice masses shows that, with the warming of the Earth at the end of the last Ice Age, CO2 increased from 0.19 to 0.3%. This change is believed to have occurred over several thousands of years; yet, in ice 40,000 yr old, such a change occurred in several hundred years. A sudden melting of the Antarctic ice mass would pose a great danger. Gradual melting of large ice masses would result in a rise of sea level by only 5-6 m. A model has been developed showing that the anthropogenic excess of CO2 causes a decomposition of deep sea sediments. If, in the worst case, all fossil fuels have been consumed by 2100, the neutralizing action of these sediments will have been exhausted. A protective layer of carbonate-free sediment will have formed on the ocean bottom, which would suddenly bring to a standstill the CO2 absorption. Alone, the atmospheric CO2 concentration would double in 12,000 yr.

27. Solow, A. R., and James M. Broadus. Woods Hole Oceanogr. Inst.
On the detection of greenhouse warming.
Climate Change, Dordrecht, 15(3): 449-453, Dec. 1989. Refs., figs.

Abstract: Two facts that have been cited as evidence of the onset of greenhouse warming are the extent to which the most recent value in a global temperature series is unusually warm and the observation that the four warmest years on record occurred in the 1980's. The authors examine these results in more detail and address the question as to whether these facts constitute evidence in favor of the detection of greenhouse warming. They conclude that they do not support detection unless one is prepared to attribute all warming in the data to the greenhouse effect.

28. Strickland, R. M. School of Fisheries, Univ. of WA., Seattle.
Definition and characterization of data needs to describe the potential effects of increased atmospheric CO2 on marine fisheries from the northeast Pacific Ocean.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/NBB- 0075, 139 p., Dec. 1985. Refs., figs., Tables. Available from NTIS, Springfield, Va. 22161

Abstract: This study evaluates the effects of increased CO2 in the atmosphere upon the climate, the ocean currents, and the resulting fish populations and potential catch, with special reference to the northeast Pacific Ocean and the Bering Sea. A northward movement of the subtropical (Pacific) anticyclone and resulting warmer waters in the Aleutians, Bering Sea, and Gulf of Alaska would alter the types and numbers of fish in any given area. Not only temperature and dissolved oxygen in the sea would change significantly but also increased dissolved CO2 content would have a less significant effect. Case studies of individual fish species in the area were made (Alaskan pollock, Pacific herring, pink shrimp, and yellowfin sole), as each are sensitive to a different combination of environmental factors such as ice cover, turbulence, coastal currents on beaches, continental shelf, or spawning grounds. Bottom-dwelling shrimp are less sensitive to temperature changes. Other case histories must be made in this and other areas since results in this study cannot be extrapolated to other areas or species. An extensive literature survey was made and APPROX. 400 references were analyzed for the study. Research and data needs are given in a two-page table and discussed together with suggestions for field surveys for planning as well as evaluation of changes that might occur.

29. Tanaka, M. T. Univ., Sendai (Japan)). Hydrogen Energy System Society, Tokyo (Japan).
Global warming by carbon dioxide and other gases. Proceedings
In: Proceedings, 9th Conference on Researches on Hydrogen Energy System. Tokyo (Japan), 17 Nov 1988, p. 43-49,59.

Abstract: The global warming by Co sub 2 , etc. was investigated. The concentration of atmospheric CO sub 2 increased at a rate of 1.3 ppM/year in 1979-1985. As the consumption of carbon in fossil fuels is 5,100 million tons/year, 54 % of released CO sub 2 remained in the atmosphere. With CO sub 2 released from living organism taken into consideration, the proportion of remaining CO sub 2 in the atmosphere is 40-45 %, indicating 56-61 % of released CO sub 2 must be absorbed in the ocean. This has raised a problem since theories in the past do not support such a high rate of absorption by the ocean and quantitative analysis is required on sources of release and absorption. Significant uncertainty is left in the estimation of CO sub 2 concentration. Temperature rise of 3 +-1.5 sup

0 C in average and 2.5 time of this value for polar regions are estimated to be caused by doubled concentration of CO sub 2 . Rapid increase in heat insulating from gas is another problem. Improved accuracy of observation and climatic models is essential for prediction of effects of CO sub 2 and other gases on climate. 6 references, 6 figures.

30. Tramoni, F.; R. G. Barry; J. Key. CIRES and Dept. of Geog., Univ. of CO., Boulder.
Lake ice cover as a temperature index for monitoring climate perturbations
Zeitschrift fur Gletscherkunde und Glazialgeologie, Innsbruck, Austria, No. 21, p. 43-49, 1985. Refs. English and German summaries.

Abstract: Records of lake freezeup and breakup in middle and higher latitudes of North America provide a little-exploited index of temperatures in the transition seasons. Regression analysis, testing several temperature indices for 27 lakes widely distributed across Canada, shows that, in half of the cases, freezing degree-day totals for the 50 days prior to freezeup give the highest correlations. Correlations with breakup are generally lower because of snow cover and other factors. A 5-day variation in freezeup date corresponds approximately to a MINUS/PLUS 1°C change in temperature for the 30 days preceding this event. Lake ice formation-decay is readily observed by weather satellites providing temperature indices as a means of detecting and assessing climatic trends.

31. Tsonis, A. A.; J. B. Elsner. Wisconsin, University, Milwaukee)
Testing the global warming hypothesis.
Geophysical Research Letters, 16:795-797, Aug, 1989.

Abstract: The temperature record for the global surface air temperature indicates that six of the warmest years occurred in the period 1980-1988. Here, the likelihood that such an arrangement is simply a manifestation of the natural variability of the system is addressed. The results indicate that the probability that such an arrangement arises naturally is between 0.010 and 0.032. (Author).

32. United States. National Oceanic and Atmospheric Administration,Environmental Research Labs., Climate Research Program, Boulder, CO.
COADS, comprehensive ocean-atmosphere data set: release 1.
Boulder, Co., April 1985, 268 p. Refs., figs.

Abstract: This report consists of three parts: Pt. 1, ''CO2 increase in the atmosphere and the role of the carbon cycle,'' describes current methods for assessing CO2 development within the carbon cycle, and discusses the results of analysis of tree ring samples, ice core samples, the instrumental record of CO2 trends, and the global measurement program. The effects on the carbon cycle produced by the role of fossil fuels, the role of the biosphere, and the role of the oceans and the global carbon cycle are surveyed. Box models, including box diffusion models, advective diffusive models, and multibox models for modelling the carbon cycle, are described. The results of assessments of future CO2 levels are summarized, involving effective airborne fraction, range of future CO2 developments, CO2 emission and concentration levels resulting from selected energy scenarios, and long-term CO2 developments. Pt. 2 examines the effect of a CO2 increase on the climate system with the aid of climate models. Two responses are investigated: 1) simulation of the climatic response to a time independent CO2 -doubling (the equilibrium response using radiation-convective models, energy balance models, and general circulation models, and the statistical significance of climate model results); and 2) climate model simulation for a time-dependent CO2 increase (transient response). This part concludes with a discussion of statistical and deterministic methods for detecting a CO2 signal. In Pt. 3, the methodology for constructing regional climate scenarios is developed. The following are considered: 1) use of analog studies in impact analysis, involving paleoclimatic and historical data (comParison of warm and cold periods and similarity methods for analyzing climatic fluctuations); 2) use of climate models in impact analysis, including model characteristics and model performance, processing of GCM-generated data, calculation of statistical parameters, and calculation of parameters for pattern comParison; 3) model verification of the temperature and precipitation rate distribution for the GISS control experiment and for the BMO control experiment; and 4) climatic change scenarios for the study area as represented by longitudinally average distributions, regional distributions, pattern comParison, and comParison of model scenarios. Analog and model scenarios are compared.

33. United, States. National Oceanic and Atmospheric Administration,Environmental Research Labs., Boulder, CO.
Geophysical Monitoring for Climatic Change, Summary reports.

Abstract: These annual documents present a summary of the research operations and accomplishments by the Geophysical Monitoring for Climatic Change (GMCC) program and by outside investigators working cooperatively with GMCC. It includes descriptions of management and operations at the four baseline stations of GMCC (Mauna Loa, Barrow, Samoa, and South Pole), scientific data from the measurement projects, and conclusions from analyses of data and of recent basic research achievements. These four stations conduct background measurements on carbon dioxide, total ozone, ozone vertical distribution, surface ozone, stratospheric water vapor, halocarbons and N2O, surface aerosols, solar radiation, station climatology, and precipitation chemistry. The individual special projects and the cooperative programs are described, and results obtained are presented.

34. White, M. R. (ed.). Biol. and Medicine Div., Lawrence Berkeley Lab., CA. **Characterization of information requirements for studies of CO2 effects: water resources, agriculture, fisheries, forests, and human health.**
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0236, 235 p., Dec. 1985.

Abstract: There are many uncertainties concerning the carbon cycle and the direct effects of CO2 . Because of these uncertainties, it is currently not feasible to conduct an impact assessment of the indirect effects of CO2 . This study seeks to define and characterize the information and data required for quantifying indirect effects, including the requirements from direct effects research and from within the fields in which indirect effects may occur. The purpose is to 1) inform the direct effects researchers of the specific needs for quantifying the indirect effects, and 2) to determine whether additional data are required and improvements needed in research techniques (e.g., data collecting methods and modelling) within the fields where indirect effects may occur.

35. Wood, F. B. (Off. Technol. Assessment, Wash., D.C.).
Monitoring global climate change: the case of greenhouse warming.
Bulletin of the American Meteorological Society, Boston, 71(1):42-52, Jan. 1990.

Abstract: Recent record high temperatures and drought conditions in many regions of the United States have prompted heightened concern about whether these are early manifestations of the global greenhouse warming projected by the major climate models. An improved global climate monitoring and reporting capability is urgently needed in order to ensure that interpretation of climate trends and comParison with model projections are based on the most complete and accurate datasets available. Priority should be placed on identifying those key variables for which data are already being collected, and then integrating these quality-controlled datasets into one consolidated climate monitroing report that would be issued at regular intervals. Quality control is essential in order to avoid errors in the datasets that lead to misleading interpretations. Data on several key variables indicate that the pattern or fingerprint of climate change during the 1980's has both significant similarities and differences when compared with the pattern projected by the major climate models for an equilibrium response to a doubling of atmospheric carbon dioxide. Overall, the present state of the global climate appears to be at a critical juncture, with improved monitoring an important prerequisite for reliably tracking climate change over the next few years.

Predicting Global Climate Change

1. Bell, T. L. Lab. for Atmos., Goddard Space Flt. Ctr., Greenbelt, MD.
Theory of optimal weighting of data to detect climatic change.
Journal of the Atmospheric Sciences, Boston, 43(16): 1694-1710, Aug. 15, 1986. Refs.

Abstract: A search for climatic change predicted by climate models can easily yield unconvincing results because of climatic noise, the inherent, unpredictable variability of time-averaged atmospheric data. A weighted average of data is described which maximizes the probability of detecting predicted climatic change. To obtain the optimal weights, an estimate of the covariance matrix of the data from a prior data set is needed. This introduces additional sampling error into the method. It is shown how to take this into consideration. A form of the weighted average is found whose probability distribution is independent of the true (but unknown) covariance statistics of the data and of the climate model prediction. A table of critical values for statistical testing of the weighted average is given, based on Monte Carlo calculations. The results are exact when the prior data set consists of temporally uncorrelated samples.

2. Bengtsson, L.; J. Shukla. European Ctr. for Medium-Range Weather Forecasts, Reading, Eng.; Ctr. for Ocean-Land-Atmos. Interactions, Dept. of Met., Univ. of MD., College Park.
Integration of space and in situ observations to study global climate change.
American Meteorological Society, Boston, Bulletin, 69(1): 1130-1143, Oct. 1988.

Abstract: The currently available model-based global data sets of atmospheric circulation are a by-product of the daily requirement of producing initial conditions for numerical weather prediction (NWP) models. These data sets have been useful for studying fundamental dynamical and physical processes, and for describing the nature of the general circulation of the atmosphere. However, because of limitations in the early data assimilation systems and inconsistencies caused by numerous model changes, the available model-based global data sets may not be suitable for studying global climate change. A comprehensive analysis of global observations based on a four-dimensional data assimilation system with a realistic physical model should be undertaken to integrate space and in situ observations to produce internally consistent, homogeneous multivariate data sets for the Earth's climate system. The concept is equally applicable for producing data sets for the atmosphere, the oceans, and the biosphere, and such data sets will be useful for studying global climate change.

3. Bjorkstrom, A. Dept. of Met., Arrhenius Lab., Univ. of Stockholm, Sweden. **One-dimensional and two-dimensional ocean models for predicting the distribution of CO2 between the ocean and the atmosphere.**
In: Trabalka, John R.; Reichle, David E. (eds.), Changing Carbon Cycle: a Global Analysis. N.Y., Springer-Verlag, Incorporated, p. 58-278, 1986. Refs., Figs.

Abstract: The approaches that have been pursued in constructing mathematical models of the circulation of carbon between the atmosphere and the ocean are reviewed. The categories of the data most useful for checking oceanic carbon models are described: data on natural distribution of the radioactive isotope C-14 in various parts of the ocean; data on atmospheric CO2 contents since the beginning of accurate observations in the 1950s; data on the Suess effect; data on radiocarbon and tritium (H-3) produced at the atmospheric bomb tests; biological tracers; and oceanographic constraints. The two-box model; diffusion models; models of polar outcropping; models of circulation systems; the realistic geographic resolution in the choice of the number of parameters of box models; future model improvements; and predictions of future CO2 levels are described.

4. Boer, G. J. (ed.).
Research activities in atmospheric and oceanic modelling. CAS/JSC Working Group on Numerical Experimentation.
World Climate Research Programme, Geneva, Report No. 9, Sept. 1986.

Abstract: This report consists of contributions obtained in response to a letter sent to APPROX. 750 scientists worldwide. In many cases, the responses are simply summaries of published work, brief descriptions of work being conducted without results, and in some instances, results of new experiments. The contributions are grouped under the following categories: 1) data analysis, initialization, and impact; 2) data sets and diagnostic studies; 3) computational aspects; 4) resolution and parameterization; 5) regional and smaller scale models and studies; 6) forecast models and studies; 7) general circulation and climate models and studies; and 8) ocean, ice, and coupled models.

5. Bolin, B. Dept. of Met., Arrhenius Lab., Univ. of Stockholm, Sweden.
How much CO SUB 2 will remain in the atmosphere? The carbon cycle and projections for the future.
In: Greenhouse Effect, Climatic Change, and Ccosystems. Chichester, Eng., John Wiley & Sons, p. 93-155, 1986.

Abstract: The aspects of the global cycle which are important for determination of probable future atmospheric CO SUB 2 concentrations are examined by considering time scales <20,000-30,000 yr and disregarding lithospheric processes except those of erosion, chemical denudation, and sedimentation. The following aspects of the global carbon cycle are discussed: 1) carbon in nature (key chemical compounds and reactions) and carbon isotopes; 2) atmospheric CO2 , the C-13 and C-14 contents of atmospheric CO2 , and the mixing of tropospheric air; 3) air-sea exchange (rate of transfer and chemical buffering); 4) carbon in the sea (total carbon and alkalinity; photosynthesis, decomposition, and dissolution of biogenic material; C-14 in the sea; ocean sediments;

and transfer processes within the sea); 5) modelling the role of oceans in the carbon cycle; 6) carbon in terrestrial biota and soils (carbon in biota and the rate of primary production, changes in the amount of carbon in terrestrial ecosystems, and modelling changes of carbon storage and isotope composition in terrestrial ecosystems); 7) global carbon cycle modelling (model features, simulation of past changes, and the concept of airborne fraction); and 8) projections of future atmospheric CO SUB 2 concentrations, use of the concept of airborne fraction for extrapolation, use of carbon cycle models, estimates of the range of future atmospheric CO2 concentrations, and emission strategies).

6. Bryan, K.; S. Manabe; M. J. and Spelman. Geophys. Fluid Dynamics Lab./NOAA, Princeton Univ., N.J.
Interhemispheric asymmetry in the transient response of a coupled ocean-atmosphere model to a CO2 forcing.
Journal of Physical Oceanography, Boston., 18(6): 851-867, June 1988.

Abstract: Numerical experiments are conducted by using a general circulation model of a coupled ocean-atmosphere system with idealized geography to explore the transient response of climate to a rapid increase of atmospheric carbon dioxide. The computational domain of the model is bounded by meridians 120° apart, and includes two hemispheres. The ratio of land to sea at each latitude corresponds to the actual land-sea ratio for the present geography of the Earth. At the latitude of the Drake Passage, the entire sector is occupied by ocean. In the equivalent of the Northern Hemisphere, the ocean delays the climate response to increased atmospheric carbon dioxide. The delay is of the order of several decades, a result corresponding to previous modelling studies. At high latitudes of the equivalent of the ocean-covered Southern Hemisphere, there is no warming at the sea surface, and even a slight cooling over the 50-yr duration of the experiment. Two main factors appear to be involved: the very large ratio of ocean to land in the Southern Hemisphere, and the very deep penetration of a meridional overturning associated with the equatorward Ekman transport under the Southern Hemisphere westerlies. The deep cell delays the response to carbon dioxide warming by upwelling unmodified waters from great depth. This deep cell disappears when the Drake Passage is removed from the model.

7. Bryan, K.; M. J. Spelman. Geophys. Fluid Dynamics Lab./NOAA, Princeton Univ., N.J.
Ocean's response to a CO2 -induced warming.
Journal of Geophysical Research, Wash., D.C., 90(C6): 11679-11688, Nov. 20, 1985. Refs., figs.

Abstract: The climatic response to a large increase in atmospheric CO2 was investigated in a numerical experiment with a coupled ocean-atmosphere model. The study is focused on one aspect of the experiment, the predicted response of the ocean to the warming episode. A fourfold increase in atmospheric CO2 causes a warming sufficiently intense to produce a partial collapse of the thermohaline circulation of the ocean. Surprisingly, the wind-driven circulation of the ocean is maintained without appreciable change. The global hydrological cycle intensifies without a major shift of the pattern of net precipitation over the model ocean. In the warming episode, the downward pathways for heat, which include diffusion and Ekman pumping, remain open. The partial collapse of the thermohaline circulation closes the normal upward pathways associated with abyssal upwelling and high-latitude convection. As a result, the thermocline is able to sequester almost twice as much heat than would be predicted from the behavior of a neutrally buoyant tracer introduced at the surface under normal climatic conditions. An enhanced sequestering of heat would produce a negative feedback for greenhouse warming. However, the partial collapse of the thermohaline circulation found in the numerical experiment would also affect the global carbon cycle, possibly producing a climatic feedback as strong as that caused by an enhanced uptake of heat from the atmosphere.

8. Cohen, S. J.; T. R. Allsopp. Atmos. Environ. Serv., Canadian Climate Ctr., Downsview, Ontario; Atmos. Environ. Serv., Ontario Region, Toronto, Canada.
Potential impacts of a scenario of CO2 -induced climatic change on Ontario, Canada.
Journal of Climate, Boston., 1(7): 669-681, July 1988.

Abstract: In 1984, Environment Canada, Ontario Region, with financial and expert support from the Canadian Climate Program, initiated an interdisciplinary pilot study to investigate the potential impact of a climate scenario, which might be anticipated under doubling of atmospheric CO SUB 2 conditions, upon Ontario. Many uncertainties were involved in the climate scenario development and the impacts modelling. Time and resource constraints restricted this study to one climate scenario and to the selection of several available models that could be adapted to these impact studies. The pilot study emphasized the approach and process required to investigate potential regional impacts in an interdisciplinary manner rather than to produce a forecast of the future. The climate scenario chosen was adapted from experimental model results produced by the Goddard Institute for Space Studies (GISS), coupled with current climate normals. Gridded monthly mean temperatures and precipitation were then used to develop projected biophysical effects. For example, existing physical and/or statistical models were adapted to determine impacts upon the Great Lakes net basin supplies, level and outflows, streamflow subbasin, snowfall, and length of snow season. The second phase of the study addressed the impacts of the climate system scenario upon natural resources and resource-dependent activities. For example, the impacts of projected decreased lake levels and outflows upon commercial navigation and hydroelectric generation were assessed. The impacts of the climate scenario upon municipal water use, residential heating and cooling energy requirements, opportunities and constraints for food production, and tourism and recreation were determined quantitatively where models and methodologies were available qualitatively. First-order interdependences of the biophysical effects of the climate scenario and resource- dependent activities were evaluated qualitatively in a workshop format culminating in a series of statements on 1) possible preventive, compensatory, and substitution strategies and 2) an assessment of current knowledge gaps and deficiencies, with recommendations for future areas of research.

9. Covey, C.; Starley L. Thompson. Lawrence Livermore Nat'l Lab., Livermore, CA and NCAR, Boulder, CO.
Testing the effects of ocean heat transport on climate.
Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section), 75(4):331-341, Dec. 1989.

Abstract: An atmospheric general circulation model was run with boundary conditions representing different amounts of equator-to-pole oceanic heat transport. Oceanic heat transport underneath sea ice was held fixed, minimizing positive feedbacks due to sea ice and thereby providing a lower bound on the effects of oceanic heat transport on climate. When oceanic heat transport is reduced, some compensating increases in atmospheric heat transport occur, but tropical surface temperatures increase and atmospheric circulation and precipitation patterns undergo significant changes. It is concluded that the ability of the oceans to generate past and future climatic changes through transport of heat is substantial, even though it is limited by a tendency of the atmosphere to partly compensate for changes in oceanic heat transport.

10. Covey, C.; E. J. Barron. Atmos. and Geophys. Sci. Div., Phys. Dept., Lawrence Livermore Natl. Lab., CA.; Earth System Sci. Ctr., PA. State Univ.
Role of ocean heat transport in climatic change.
Earth-Science Reviews, Amsterdam, Netherlands., 24(6): 429-445, Feb. 1988.

Abstract: Although heat transport by the oceans is comparable in magnitude to heat transport by the atmosphere, and changes in oceanic heat transport have often been invoked to explain past climatic changes, there has been little explicit investigation of the sensitivity of climate to ocean heat transport. Some theoretical studies using general circulation models (GCMs) of the Earth's atmosphere and oceans suggest that the climatic effect of a change in ocean heat transport may be moderated by a tendency of the atmosphere to compensate by changing its heat transport in the opposite sense. If this compensation effect exists, rethinking of the role of ocean heat transport in both paleoclimates and possible future climatic change is warranted.

11. Cushman, R. M.; Penny N. Spring. Environ. Sci. Div., ORNL.
Differences among model simulations of climate change on the scale of resource regions.
Environmental Management, New York., 13(6): 789-795, Nov/Dec 1989.

Abstract: The climate simulations from atmospheric general circulation models (GCMs) are often used to analyze the potential effects of climate change on environmental resources. It has been demonstrated that there are differences among the simulations from various GCMs, on spatial scales ranging from global to regional. This paper quantifies the differences in temperature and precipitation simulated by three major GCMs for four specific regions: an agricultural region (the North American winter wheat belt), a hydrologic region (the Great Basin), a demographic region (the high-density population corridor of the northeast United States), and a political region (the state of Texas). Both the current (control) and the climatic response to a doubling of atmospheric carbon dioxide (CO2) are considered. In each region, even when the data are averaged on a seasonal basis, marked differences occurred in the areal average climate simulated by the different GCMs for both the control climate and the doubled-CO2 climate. Thus, climate impact sutides based on the simulations of more than one GCM could easily yield a range of possible results.

12. Dickinson, R. E. Natl. Ctr. for Atmos. Res., Boulder, CO.
How will climate change? The climate system and modelling of future climate.
In: Greenhouse Effect, Climatic Change, and Ecosystems. Chichester, Eng., John Wiley & Sons. p. 207-270, 1986.

Abstract: The methodology of modelling climatic change as a result of the greenhouse effect and projected climatic changes are reviewed. The following topics are considered: 1) possible causes of climatic change in the conditions of particular solar output, orbital variations, volcanic eruptions, and atmospheric composition; 2) types of models of the climate system (reasons for different models, zero-dimensional models, one-dimensional models, energy balance climate models, ice-albedo feedback, radiative-convective models, cloud radiation feedbacks, and general circulation models); 3) model deficiencies, including relationships between different kinds of models, clouds, ocean coupling, sea ice, surface albedo, land surface hydrology, and transient response; 4) model limitations, including validation and performance of control runs, signal-to-noise problems, and regional continental scale details; 5) a review of GMC results for increased CO SUB 2 as obtained from more realistic and exploratory GCMs; and 6) reliability of model results as manifested in the global mean, consideration of the transient lag resulting from ocean heat uptake, regional patterns, and model results as a guide to detecting CO2 -induced climatic change over the next decades.

13. Dickinson, R. E.; R. J. Cicerone. Natl. Ctr. for Atmos. Res., Boulder, CO.
Future global warming from atmospheric trace gases.
Nature, London, 319(60499): 109-115, Jan. 15, 1986. Refs., figs.

Abstract: Human activity during the 20th century has increased the concentrations of atmospheric trace gases, which in turn has elevated global surface temperatures by blocking the escape of thermal IR radiation. Natural climate variations are masking this temperature increase, but further additions of trace gases during the next 65 yr could double or even quadruple the present effects, causing the global average temperature to rise by at least 1°C and, possibly, by >5°C. If the rise continues into the 22nd century, the global average temperature may reach higher values than have occurred in the past 10 million yr.

14. Dowd, R. M.
Greenhouse effect.
Environmental Science & Technology, Wash., D.C, 20(8): 767, Aug. 1986.

Abstract: Historically, the issues of ozone depletion and the greenhouse effect have been treated separately. Recent research has shown, however, that the ozone and greenhouse issues are strongly coupled; the same gases that are predicted to modify ozone are also predicted to produce climate warming. Recent NASA modelling work seems to indicate that temperature increases resulting from CO2 in the atmosphere are approximately equivalent to temperature increases that would be expected from all other trace gases combined.

15. Esser, G. F B Biol./Chem. of the Univ., General Ecol. Group, Osnabruck, W.Germany.
Sensitivity of global carbon pools and fluxes to human and potential climatic impacts
Tellus, Series B, Chemical and Physical Meteorology, Stockholm, 39(3): 245-260, July 1987. Refs., figs.

Abstract: Besides the emissions from fossil sources, the anthropogenic land use (clearings and similar influences) changes the CO2 fertilization effect on the biosphere, and potential climatic fluctuations may have influenced the global carbon balance and the CO2 concentration of the atmosphere in the period 1860-1981. A sensitivity study was conducted to compare the importance of these impacts for the behavior of fluxes and pools in biosphere, atmosphere, and ocean. The Osnabruck Biosphere Model, a regionalized carbon flux model for the terrestrial biosphere, was coupled with a box diffusion ocean model and a one-box atmosphere model. A regional land-use pattern was derived from the ''World Atlas of Agriculture.'' Its dynamics were introduced by using data of global land-use changes. For the simulation of climatic variations, standardized changed levels as well as gradients of temperature and precipitation were used. In the period 1860-1981, land- use changes and the CO2 fertilization effects are similarly important and roughly amount to four fifths of the fossil source. Effects of potential climatic fluctuations may not exceed one fifth of that amount.

16. Friedman, H. Commission on Phys. Sci., Math., and Resources, Natl. Res. Council, Wash., D.C.
Some interdisciplinary aspects of Sun-Earth relationships in the study of global change

In: Malone, Thomas F.; Roederer, Juan G. (eds.), Global Change. Cambridge, Eng.:Cambridge University Press, 1985. p. 365-370. (ICSU Press Symposium Series, No. 5).

Abstract: The current state of knowledge of Sun-Earth relationships in the course of global change is reviewed. The following are considered: the role of orbiting factors and vulcanism in producing climate change; the possible role of the atmosphere in producing the Chandler wobble; the changes in the length of day on the order of decades, which may be due to the coupling of the fluid core to the mantle and the ultimate formation of the geomagnetic field, etc.; the global electric circuit; and the interrelationship of ground currents, electric fields, and thunderstorm frequency with auroras and variations in solar activity.

17. Georgii, H. W. Inst. fur Met. und Geophys., Univ. of Frankfurt, Frankfurt a./M.
Weitere klimarelevante Spurengase. [Further effects of trace gases on climate.]
Promet: Meteorologische Fortbildung, Offenbach a./M., 15(4): 5-12, 1985. Refs., tables.

Abstract: The role of trace gases in modifying climate is surveyed. Trace gases, as compared with atmospheric CO2 , have a concentration of a factor 100 to 1000 lower than that of CO2 ; nevertheless, they exert an effect upon climate. A table gives the following data on atmospheric trace gases: mixing ratio in clean air, total amount in the atmosphere, residence time, and absorption bands. This is followed by a detailed discussion of the properties, sources, sinks, etc., of short- and long-lived trace gases. Nitrous oxide, methane, chlorofluoromethane; carbon monoxide and tropospheric ozone, including the sources of global CO, and the chemistry of CO and of methane oxidation; and estimation of the future changes in global trace gases concentration up to 2050 are discussed with regard to long-lived trace gases.

18. Gibbs, M. J.; J. S. Hoffman. ICF Inc., Wash., D.C.; U.S. EPA.
Approach for generating climate change hypotheticals, given limitations in current climate models.
In: Shands, William E.; Hoffman, John Stephen (eds.), Greenhouse effect, climate change, and U.S. forests. Wash., D.C., Conservation Foundation, p. 91-111, 1987.

Abstract: The authors discuss 1) the need for hypothetical climate-change scenarios that describe the ways in which climate may change as a result of greenhouse warming, and 2) a method for creating such scenarios by using outputs from current climate models. The need to make preliminary estimates of the probable impacts of the impending climate change drives the desire for geographically and temporally resolved estimates of climate change. Such estimates will permit a determination to be made of the value of investing additional resources in scientific research to improve the ability to forecast regional climate change over time. A method for developing internally consistent hypothetical scenarios is proposed, and examples of the estimates obtained are presented.

19. Golitsyn, G. S. Inst. Fiz. Atmos., Akad. Nauk, U.S.S.R.
Izmeneniya klimata a XX i XXI stoletiyakh (obzor). [Climate changes in the 20th and 21st centuries (a review).]
Akademiya Nauk SSSR, Moscow, Izvestiya, Fizika Atmosfery i Okeana, 22(12): 1235-1252, Dec. 1986. Refs. Transl. into English in corresponding issue of Izvestiya, Atmospheric and Oceanic Physics, Wash., D.C.

Abstract: The author reviews studies of the climate changes performed during recent years. To a substantial degree, this review is based upon the material of the Villach conference (Austria, Oct. 1985) on the assessment of the role of CO2 and other greenhouse gases in climate changes and related impacts. Problems considered are related to CO2 emissions into the atmosphere, the carbon cycle in nature, and variations of the atmospheric CO2 in the past since 150,000 yr B.P. Other optically active gases are also discussed (Freons, methane, ozone, and N2O, in order of their importance), which in 50 yr can produce an effect similar to or slightly larger than CO SUB 2 and together with the latter can change the budget of the thermal radiation at the upper boundary of the troposphre by -4 W/m SUPER 2 , which is equivalent to CO2 doubling. Empirical investigations of the climate are described, including precipitation, by paleoclimatic methods and instrumental observation analyses. The global time series of the mean annual surface air temperature obtained for the first time reveals a warming trend of 0.55 K/100 yr. The mean ocean level is analyzed which gives its rise by 10-15 cm for the last 100 yr mainly because of the thermal expansion of water. Model studies of the climate sensitivity to CO2 doubling are reviewed for temperature, precipitation, and soil water storage. Biota reaction on the CO2 increase and climate change is described, and a possible favorableness of these changes is noted for temperature and higher latitudes.

20. Grotch, S. L. Atmos. and Geophys. Sci. Div., Lawrence Livermore Natl. Lab., CA.
Regional intercomparisons of general circulation model predictions and historical climate data
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/NBB- 0084, 291 p., April 1988.

Abstract: The author intercompares 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, the Geophysical Fluid Dynamics Laboratory of NOAA, and the Goddard Institute for Space Studies of NASA 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 is the Oregon State University GCM (OSU, Schlesinger, 1986), results for which did not become available until after publication of the SOA. Only two model variables are examined in this paper: 1) surface air temperature, and 2) precipitation. These variables were considered for both seasonally and annually averaged periods, for both the current climatic conditions and the predicted equilibrium changes after a doubling of the CO SUB 2 concentration. For the current climate (1 MULTIPLIED BY CO SUB 2), the model results for these two variables were compared with each other and with several data sets representing observed climate conditions over recent 15-30-yr 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° lat. MULTIPLIED BY 5° long. to 8° lat. MULTIPLIED BY 10° long.; the data are typically available with similar resolution. Thus, each data point (on the model or observation grid) represents a region of APPROX. 400 MULTIPLIED BY 400 km or larger or approximately 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. In this paper, the major focus is the intercomParison of models and data over a range of scales: global, hemispheric, zonal, continental, and regional (typically representing 5-20 model grid points). 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 grid points?'' 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.

21. Gutowski, W. J. Atmos. and Environ. Res., Inc., Cambridge, MA.
Surface energy balance of three general circulation models: current climate and response to increasing atmospheric CO2.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER/60422- H1, 119 p., May 1988.

Abstract: The surface energy balance simulated by state-of-the-art general circulation models at GFDL, GISS, and NCAR for climates with current CO2 concentration (control climate) and with twice the current levels is examined, and the simulated balances are compared by averaging fields of interest over a hierarchy of spatial domains ranging from the entire globe down to regions a few hundred kilometers across. The models and the data are described, and the surface energy balance equations are presented. Data are used to discuss the global mean, the zonal mean, and the regional mean of the energy balance for the three models. For the global average control climate, individual fluxes of sensible heat, latent heat, short-wave radiation, and upward (LW UP ARROW) and downward (LW DOWN ARROW) long-wave radiation agree among the models to within 25 Wm SUPER - SUPER 2 . In all three models, the surface energy balance is dominated by long-wave radiation (the greenhouse effect). Other surface fluxes are smaller, but the models also agree on their relative magnitudes. Although the 25-Wm SUPER - SUPER 2 difference is only a small fraction of the largest fluxes, LW UP ARROW and LW DOWN ARROW , the difference is a large fraction of the net long-wave radiation at the surface (APPROX. 60 Wm SUPER - SUPER 2), and it is as large as any of the global average, seasonal changes in these fluxes. Global average changes in surface fluxes, when CO2 doubles, agree between models within 3 Wm SUPER - SUPER 2 . Spatial variation of net long-wave radiation at the surface is small compared with the spatial variability of near-surface air temperature and moisture. Intermodel differences in doubling CO2 surface flux changes to 100 Wm SUPER - SUPER 2 occur near the limits of polar ice caps. Differences between models for surface fluxes in regions a few hundred kilometers across are often closely linked to differences in zonal mean climatology. Differences of parameterization of ocean ice create discrepancies between models. Additional discrepancies also occur in regional scales that are not only quantitative, but also qualitative. Precipitation and its change are simulated more consistently than surface temperatures and fluxes.

22. Hansen, J. NASA/Goddard Space Flt. Ctr., Goddard Inst. for Space Studies, N.Y.
Global climate changes as forecast by Goddard Institute for Space Studies: three-dimensional model.
Journal of Geophysical Research, Wash., D.C., 93(D8): 9341-9364, Aug. 20, 1988.

Abstract: The authors use a three-dimensional climate model, the Goddard Institute for Space Studies (GISS) model 2 with 8 MULTIPLIED BY 10° horizontal resolution, to simulate the global climate effects of time-dependent variations of atmospheric trace gases and aerosols. Horizontal heat transport by the ocean is fixed at values estimated for today's climate, and the uptake of heat perturbations by the ocean beneath the mixed layer is approximated as vertical diffusion. The authors make a 100-yr control run and perform experiments for three scenarios of atmospheric composition. These experiments begin in 1958 and include measured or estimated changes in atmospheric CO2 , CH4 , N20, chlorofluorocarbons (CFCs), and stratospheric aerosols for the period from 1958 to the present. Scenario A assumes continued exponential trace gas growth; scenario B assumes a reduced linear growth of trace gases; and scenario C assumes a rapid curtailment of trace gas emissions such that the net climate forcing ceases to increase after the year 2000. Principal results from the experiments are given. Global warming to the level attained at the peak of the current interglacial and the previous interglacial occurs in all three scenarios; however, there are dramatic differences in the levels of future warming, depending upon trace gas growth. The greenhouse warming should be clearly identifiable in the 1990s; the global warming within the next several years is predicted to reach and maintain a level at least three standard deviations above the climatology of the 1950s. Regions where an unambiguous warming appears earliest are low-latitude oceans, China and interior areas in Asia, and ocean areas near Antarctica and the North Pole; aspects of the spatial and temporal distribution of predicted warming are clearly model dependent, implying the possibility of model discrimination by the 1990s and, thus, improved predictions, if appropriate observations are acquired. The temperature changes are sufficiently large to have major impacts on people and other parts of the biosphere, as shown by computed changes in the frequency of extreme events and by comParison with previous climate trends. The model results suggest some near-term regional climate variations, despite the fixed ocean heat transport that suppresses many possible regional climate fluctuations; e.g., during the late 1980s and in the 1990s, there is a tendency for greater than average warming in the southeastern and central U.S. and relatively cooler conditions or less than average warming in the western U.S. and much of Europe. Principal uncertainties in the predictions involve the equilibrium sensitivity of the model to climate forcing, the assumptions regarding heat uptake and transport by the ocean, and the omission of other, less certain climate forcings.

23. Hansen, J. Goddard Space Flt. Ctr., Inst. for Space Studies, N.Y.
Greenhouse effect: projections of global climate change.
In: United States. Environmental ProtectionAagency/United Nations Environment Programme, Effect of Changes in Stratospheric Ozone and Global Climate, vol. 1, Overview. Wash., D.C., Aug. 1986. p. 199-218. Refs., figs. (International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, June 16-20, 1986, Proceedings)

Abstract: Projections of global climate during the next several decades are presented, based principally on climate model simulations in which atmospheric CO2 and trace gases increase steadily at rates estimated from observations. This is the first time that a global climate model has been used for simulating the climate effects of the transient growth of greenhouse gases, and as such, it permits an estimate of when the greenhouse effect should begin to be evident above the level of natural climate variability. The authors emphasize that a number of caveats must be attached to the climate model results. But it is also stressed that the climate sensitivity of the model has been extensively compared to the sensitivity of other models and is consistent with available empirical evidence from past climate changes. The presentation is organized as a response to a letter from Chairman John Chafee of the U.S. Senate subcommittee on Environmental Pollution of the Committee on Environment and Public Works who requested testimony at a hearing on the greenhouse effect on June 10, 1986. Specifically, his letter asked that the following topics be addressed: the nature of the work in modelling greenhouse climate effects and how the models are tested to determine their validity.

24. Hanson, K.; G. A. Maul; T. R. Karl. NOAA Air Resources Lab., NOAA Atl. Ocean. and Meteorol. Lab., and NOAA Nat'l Clim. Data Ctr.
Are atmospheric "greenhouse" effects apparent in the record of the contiguous U.S. (1895-1987)?
Geophysical Research Letters, 16(1):49-52, Jan. 1989.

Abstract: The temperature and precipitation climate records for the United States were examined. These records consist of area averages across the contiguous United States and northern plains. They are based on as many as 6000 stations. Time series of these data were

tested for constancy of the mean using the Spearman rank test and two-phase regression. Test results indicate that overall trends are near zero. The only evidence for a long-term trend is in fall precipitation for the contiguous United States. This trend appears to result from higher fall precipitation during the period 1970-1987 compared to the remainder of the period (1895-1969).

25. Hoffert, M. I.; B. P. Flannery. N.Y. Univ.; Exxon Res. and Engr. Co., Linden, N.J.
Model projections of the time-dependent response to increasing carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER 0237, Dec. 1985. p. 148-190. Refs., figs.

Abstract: This article constitutes a review and analysis of the fundamental problems in the modelling of transient climatic changes in response to slowly increasing atmospheric CO concentration. A conceptual model for understanding the transient response of global climate is presented which involves the use of energy balance models (EBMs) that sacrifice detail for clarity of analysis by focusing on the principle of conservation of energy. The mathematical basis of this model is set forth, and some results of its application are presented. Highly simplified model equations that describe the behavior of the time scales of various processes that come into play during the transient response are set forth. Factors driving transient climate change are discussed, e.g., carbon dioxide and trace gas forcing, solar forcing, and volcanic and stratospheric aerosol forcing. Transient model results are reviewed, including horizontally averaged models, latitudinal effects, and some recent findings of testing of transient models. Recommendations for necessary further research are presented.

26. Jain, A. K.; M. Lal; M. C. Sinha. Ctr. for Atmos. Sci., Indian Inst. of Tech., New Delhi.
Study on the effects of doubling of CO2 on the Earth's climate with a 2-D radiative-convective model.
World Climate Research Programme, Geneva, Report No. 9, Sept. 1986. p. 7.37-7. 38. Abstract only. (WMO/TD- No. 141)

Abstract: A two-dimensional radiative-convective model has been developed to calculate mean annual zonally averaged temperature profiles for 18 latitudinal belts of 10° width each. The model includes meridional heat transport, surface albedo feedback, and lapse rate feedback. Because of the flexibility and computational efficiency as compared to three-dimensional general circulation models, this model may serve as a useful tool in studying the climate sensitivity to external forcings. The model has been successfully applied to reproduce the meridional variation of climatic elements for the presentday atmosphere. Next, the sensitivity of the climate to a doubling of the atmospheric CO2 content is examined. The surface temperature response ranges from APPROX. 1.6°C near the Equator to 4°C in the polar regions, with a global mean of 2.1°C. One of the interesting features is that the maximum response resulting from doubling of CO2 in the atmosphere descends from the upper troposphere at low latitudes to the surface at high latitudes. The responses of the transport of sensible and latent heat are in opposite direction, thus leading to only slight but positive changes in the total meridional heat flux.

27. Kagan, B. A.; N. B. Maslova. Inst. Okean.
Otsenka effekta vzaimodeystviya uglerodnogo i termodinamicheskogo tsiklov v sisteme okean-atmosfera. [Evaluation of the effect of the interaction of the carbon and thermodynamic cycles in the ocean-atmosphere system.]
Meteorologiya i Gidrologiya, Moscow, No. 10, Oct. 1986. p. 66-75. Refs. English and russian summaries. Transl. into English in corresponding issue of Meteorology and Hydrology, Wash., D.C. Available from NTIS, Springfield, VA. 22161.

Abstract: An approximate analytical solution is obtained for the coupled temporal evolution of carbon and thermodynamic cycles in the ocean-atmosphere system. It is realized that, until 2020, the change in the thermal regime actually will have no effect on the excess carbon content in different parts of the climate system (on condition that the Industrial Revolution began in 1860). This result is a strong argument for the a priori assumption that temporal evolution can be studied separately for the carbon and thermodynamic cycles.

28. Kagan, B. A.; V. A. Ryabchenko; A. S. Safray. Inst. Okean., Akad. Nauk, U.S.S.R.
Chislennyye eksperimenty po otsenke reaktsii sistemy okean-atmosfera na antropogennyye izmeneniya rastitel'nogo pokroVa. [Numerical experiments on estimates of the response of the ocean-atmosphere system of anthropogenic changes in the vegetable cover.]
Akademiya Nauk SSSR, Moscow, Izvestiya, Fizika Atmosfery i Okeana, 21(8): 803-809, Aug. 1985. Refs. English and russian summaries. Transl. into English in corresponding issue of Izvestiya, Atmospheric and Oceanic Physics, Wash., D.C.

Abstract: Anthropogenic changes in the vegetable cover are accompanied by enhanced albedo of the land surface, reduced moisture content of the soil, and increased concentration of atmospheric CO2 . By using a seasonal thermodynamic model of the ocean-atmosphere system, the character and scale of possible climatic consequences of variations of these parameters are investigated.

29. Kagan, B. A.; V. A. Ryabchenko; A. S. Safray. Leningradskiy Otdel Inst. Okean. im. P. P. Shirshova.
Reaktsiya sistemy okean-atmosfera na udvoyeniye soderzhaniya atmosfernogo CO2 i yeye sezonnaya izmenchivost'. [Response of the ocean-atmosphere system to doubling of the atmospheric CO2 content and its seasonal variability.]
Okeanologiya, Moscow, 26(3): 365-375, May/June 1986. Refs. English and russian summaries. Transl. into English in corresponding issue of Oceanology, Wash., D.C.

Abstract: Estimates of the seasonal variability of the response of the ocean-atmosphere system to the doubling of the atmospheric CO2 content are given. It is shown that deviations of atmospheric surface layer temperatures in high and low latitudes are not very different from each other because of the damping effect of the ocean.

30. Kagan, B. A.; V. A. Rybchenko; A. S. Safray. Inst. Okean., Akad. Nauk, U.S.S.R.
Modelirovaniye nestatsionarnoy reaktsii sistemy okean-atmosfera na uvelicheniye kontsentratsii atmosfernogo CO2 . [Simulation of the nonsteady response of the ocean-atmosphere system to an increase in atmospheric CO2 concentration.]
Akademiya Nauk SSSR, Moscow, Izvestiya, Fizika Atmosfery i Okeana, 22(11): 1131-1141, Nov. 1986. Refs. English and russian summaries. Transl. Into English in corresponding issue of Izvestiya, Atmospheric and Oceanic Physics, Wash., D.C.

Abstract: Calculation results concerning the temporal variability of the climate system from the beginning of the Industrial Revolution to the end of the 21st century are discussed. The calculation is based on an improved version of the seasonal thermodynamical model of the ocean-atmosphere system which is suggested. In the improved model, the following two assumptions are neglected: 1) fixing of the area of sea ice, and 2) separate consideration of the carbon and thermodynamical cycles. One of the most remarkable results of the calculation is the detection of autooscillations in the polar ocean-sea ice area system of cold deep-water formation. The presence

of autooscillations contributes to the preservation of sea ice until the end of the forthcoming century.

31. Keepin, W.; I. Mintzer; L. Kristoferson. Beijer Inst. of the Royal Swedish Acad. of Sci., Stockholm; World Resources Inst., Wash., D.C.; Beijer Inst.
Emission of CO2 into the atmosphere: the rate of release of CO2 as a function of future energy developments.
In: Greenhouse effect, climatic change, and ecosystems. Chichester, Eng., John Wiley & Sons, p. 35-91, 1986.

Abstract: The feasible range of future CO2 emissions from energy-related activities is explored by analyzing numerous recently published scenarios for the future global energy system to determine how each will affect the rate and cumulative level of CO SUB 2 emissions to the atmosphere. Particular attention is paid to the underlying assumptions and uncertainties in projections of future energy developments of CO2 emissions. The following topics are discussed: the relationship of energy use, economic activity, and CO SUB 2 emissions, including energy consumption and CO2 emissions; energy supply, fuel mix, and CO2 emissions (fossil fuels and nonfossil supplies of primary energy); historical development of CO SUB 2 emissions; uncertainties in future energy use and CO SUB 2 emissions resulting from such factors as demographic uncertainties, uncertainties in future economic variables, influence of technology on CO2 emissions, uncertainties in models and projections, parametric and structural uncertainty, and methods for handling uncertainty; and the special case of developing countries. A critical review of several global energy and CO SUB 2 forecasts is presented which considers the general characteristics of modelling and forecasts and analyzes future energy and CO2 projections. The bounds of future CO SUB 2 emissions are discussed in light of comparative assessments and their validities as resulting from a comParison of studies of Nordhaus and Yohe, Edmonds and Reilly, IIASA, and Lovins et al., Goldemberg et al., and Rose et al.

32. Kiehl, J. T. Natl. Ctr. for Atmos. Res., Boulder, CO.
Climatic effects of ozone and trace gases.
Ozone symposium, 4th, Halkidiki, Greece, Sept. 3-7, 1984, Atmospheric Ozone, Proceedings.
Dordrecht, Holland,: Reidel Publ. Company, p. 103, 1985

Abstract: The climatic effects of a large number (>20) of trace gases, many of which have not been considered in previous studies, are investigated. By using a one-dimensional radiative convective model, the climatic impact of these gases is studied for three cases. 1) By using present day gas concentrations and growth rates, the effect of these gases on the equilibrium thermal structure 50 yr from now is estimated. 2) Preindustrial gas concentrations are used to estimate climatic effects that should already have taken place. 3) The relative importance for individual gases is calculated for a uniform 0-1-p.p.b.v. increase in gas concentration. The results of these calculations show that increases in CO2 from preindustrial times (1850) to the present have caused an increase in equilibrium surface temperature of 0.5 K. This effect of CO2 alone is amplified by a factor of 1.5 because of trace gases. Increases in CO2 from present concentrations to their expected levels 50 yr from now result in an increase in equilibrium surface temperature of 0.7 K. The inclusion of all other trace gases enhances this increase by a factor of 2.0. The uncertainty in this factor caused by uncertainties in gas concentrations is a change in enhancement from 1.5 to 3.0. A number of trace gases have been identified which are of potential climatic importance, based on a p.p.b.v. increase in concentration; among these are CFC-13, -22, -116, CHF SUB 3 , and CH SUB 2 F SUB 2 . The surface temperature effects, on a p.p.b.v. basis, of these gases are of similar magnitude to those caused by CFC-11 and -12. These results are compared with previous studies, and sources of differences are discussed. The results of this study are discussed in greater detail in Ramanathan et al. (1984).

33. Kondrat'yev, K. Y. Inst. of Lake Res., Lab. for Remote Sensing, Acad. of Sci.,Leningrad, U.S.S.R.
Global-scale climate changes and their causes.
Gerlands Beitrage zur Geophysik, Leipzig, 96(1): 93-103, 1987. Refs. English, German, and Russian summaries.

Abstract: Man's activities in industry and agriculture result in substantial changes of the natural environment. They can cause global climatic changes that can influence agricultural and industrial production. At present, a wide range of factors and components is known which are system parameters and, as such, play a major role in the interaction processes of atmosphere, hydrosphere, biosphere, cryosphere, and lithosphere for modelling climatic changes. However, a full parameterization of these complicated processes is not possible at present, so that the model formation is directed at stochastic predictions of climatic changes. The interaction processes known so far are comprehensively presented and evaluated in their components-atmosphere, ocean, and biosphere. Moreover, possible catastrophic climatic changes in case of a nuclear war are discussed.

34. Kondrat'yev, K. Y.
Uglekislyy gaz i klimat. Dannyye nablyudeniy i chislennogo modelirovaniya. [Carbon dioxide and climate: observational data and numerical modelling.]
Vsesoyuznoye Geograficheskoye Obshchestvo, Leningrad, Izvestiya, 119(2): 97-105, March/April 1987. Refs. Russian summary.

Abstract: The results of the most recent climate investigations according to observational data and the possibility of distinguishing with them the CO2 signal (the effect of increasing CO2 concentration on climate) are discussed. The principal results of such investigations are the inadequate reliability of existing information for confident detection of global climate trends, the complex nature of the variability, and the cause of the conditionality of climate, making it difficult to filter the CO2 signal. Another difficulty in the solution of this problem is the imperfection of existing (even the most complete) theoretical models of climate, which do not consider the entire complexity of the inverse relationships functioning in the climate system. The current state of numerical modelling of climate is analyzed. Sufficiently long and intensive investigations will be required in the future, before it becomes possible to attain a sufficiently reliable understanding of the causes of current climate variations.

35. Lal, M.; A. K. Jain; M. C. Sinha. Ctr. for Atmos. Sci., Indian Inst. of Tech., New Delhi; Indian Met. Dept., New Delhi.
Possible climatic implications of depletion of Antarctic ozone.
Tellus, Series B, Chemical and Physical Meteorology, Stockholm, 39(3): 326-328, July 1987. Refs., figs.

Abstract: The total amount of ozone overhead in late winter and early spring has decreased considerably during the past decade. Recent satellite data confirm that the column abundances of ozone at Antarctica are among the lowest recorded anywhere on the globe. The radiative-convective model calculations demonstrate that this depletion of Antarctic ozone could lead to a surface cooling of APPROX. 0.47 K, which is in contrast to that observed from climatological temperature records. This calls for a detailed investigation of the air chemistry in relation to the dynamic-radiative balance for the Antarctic atmosphere.

36. Leftus, V. Astron. Inst., Czechoslovak Acad. of Sci., Ondrejov.
Solar activity variations and climatic changes.
Studia Geophysica et Geodaetica, Prague, 30(1): 93-110, Feb. 1986. Refs. English and Russian summaries,

Abstract: For the last two millenia, it has been possible to determine the secular variation of solar activity from naked- eye sun spots, auroras, and radiocarbon variations. The results of the analysis of old East Asian observations of comets, which reflect the night cloudiness variation, do not agree with the former findings that the long-term climatic changes derived from comets depend upon solar activity. The distinct anticorrelation between the Chinese records of comets and naked-eye sun spots is found only for the period from the 3rd to the 6th century A.D., but in other centuries, little correlation is evident. East Asian cometary observations give evidence of climatic changes in different parts of this large geographic region. Secular variations of the River Nile levels, regularly measured from the 7th to the 15th century A.D., clearly correlate with the solar variations, which suggests evidence for solar influence on the climatic changes in the East African Tropics. The decline of the Kingdoms in ancient Egypt and the occurrence of the Intermediate Periods are generally explained by very low Nile floods and prolonged droughts, followed by severe famines and the destruction of the political structure. The radiocarbon data show that at least the First and Second Intermediate Periods coincide with the secular maxima of solar activity, and the Middle Kingdom with the minimum. This contradicts the positive correlation found from the eight centuries of measurements of Nile River levels made by Arabs. It seems that the influence of solar activity on the secular climatic changes has an episodic character.

37. Lockwood, J. G. School of Geog., Univ. of Leeds, Eng.
Hydrological interactions between the land surfaces and the atmosphere as a factor in climatic change.
Progress in Physical Geography, London, 11(1): 103-111, March 1987.

Abstract: The time-scale subdivision of the climate system involves 1) the fast response parts of the system, such as the atmosphere and surface layers of the ocean and continents; and 2) the slow-response parts of the systems, such as the deep ocean and ice masses, which are the time-dependent carriers of long-term climatic change. This review of the problem of the results of changes in the surface hydrology on the atmosphere considers the fast-response atmosphere-surface hydrological interaction by considering the moisture budget of the atmosphere as determined by the following components: the net flux of water vapor and liquid water across the vertical boundaries of the region; the net upward flux of water vapor from the underlying surface (evaporation less condensation); the precipitation of rain and snow from the atmosphere to the surface; surface/atmosphere interactions in warm environments; and the interrelationship of vegetation and climate.

38. Luther, F. M. Lawrence Livermore Natl. Lab., CA.
Projecting the climatic effects of increasing carbon dioxide: volume summary.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOR/ER- 0237, p. 259-272, Dec. 1985.

Abstract: The significant progress that has been made in the current understanding of the processes that constitute the climate system is summarized. These processes include physical, chemical, radiative, and dynamical processes that affect the atmosphere, the hydrosphere, the cryosphere (the snow and ice on the land or beneath the Earth's surface), and the biosphere. This is accomplished by summarizing the preceding seven chapters: 1) climate system components and processes; 2) radiative effects of carbon dioxide and trace gases; 3) methods for determining the climatic response; 4) climatic sensitivity to an increased CO2 concentration; 5) rate of climate change from the increasing CO2 concentration; 6) climatic effects of trace gases; and 7) evidence from past climate as guide to the possible characteristics of a future warmer Earth.

39. Luther, F. M.; R. D. Cess. Lawrence Livermore Natl. Lab., CA.; State Univ., N.Y.
Review of the recent carbon dioxide-climate controversy.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, P. 321-335, Dec. 1985. Appendix B, Refs. Available from NTIS, Springfield, Va. 22161.

Abstract: While model calculations of the climate impact of the increasing atmospheric CO2 concentration consistently suggest that a doubling of CO2 concentration would result in a warming of global surface air temperature by as much as several degrees Celsius, controversy arose in 1979 when Newell and Dopplick (1979) concluded that climate models were overestimating the sensitivity of the climate to doubled CO2 concentration. This article reviews the controversy that has arisen about the effect of CO2 on climate. The controversy is not about the experimental data indicating that the relationship among atmospheric emittance, vapor pressure, and surface temperature are consistent with climate model calculations; it concerns the analysis and interpretation of the results. This review contains 1) the chronology of the CO2 -climate controversy; 2) the surface energy balance equations; 3) Newell and Dopplick's surface energy balance analysis; 4) Idso's surface energy balance analysis; 5) the hypothetical case of the Earth without an atmosphere; 6) linear vs. nonlinear climate response; and 7) interpretation of climate response curves.

40. Luther, F. M.; R. G. Ellingson. Lawrence Livermore Natl. Lab., Livermore, CA.; Univ. of MD.
Carbon dioxide and the radiation budget.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, Dec. 1985. p. 25-55. Refs., figs., Tables. Available from NTIS, Springfield, Va. 22161.

Abstract: The radiative forcing of the Earth-atmosphere system, caused by an increase in CO2 levels which can lead to climate change, is discussed. The radiatively important atmospheric constituents are summarized. An overview of radiative transfer theory is presented. Computational methods for gaseous absorption are presented with the aid of the relevant equations, e.g., transmissivities for individual gases involving line-by- line techniques, narrow band models, and wide band models, and the treatment of overlapping absorption. The assessment of the accuracy of long-wave radiative transfer models is discussed on the basis of an intercomParison of radiation transfer models and a comParison of models with observations. The radiative energy budget of the unperturbed atmosphere, the radiative effect of variations in CO2 concentration, and the radiative effect of aerosols, including techniques for its calculation are reviewed.

41. Luther, F. M.; M. C. MacCracken. Lawrence Livermore Natl. Lab., CA.
Recommendations for research and modeling activities for projecting the climatic effects of increasing carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, Dec. 1985. p. 273-279. Available From NTIS, Springfield, Va. 22161.

Abstract: The overall picture is presented of the major areas where special emphasis and effort should be directed to address the key issues in obtaining a full understanding of the potential climatic effects of increased atmospheric CO2 concentration. The suggested recommendations for research are itemized as follows: 1) understanding climate processes and feedback mechanisms by evaluating and improving their representation on climate models (oceanic processes, sea and ice snow cover, and coupling of climate system components); 2) coupled modelling of simultaneous perturbation to the climate (trace gases, aerosol variation in the solar irradiance, etc.); and 3) testing and validation of climate models (simulation of present and past climate behavior and regional and seasonal variability of the frequency of extreme events).

42. MacCracken, M. C. Lawrence Livermore Natl. Lab.
Carbon dioxide and climate change: background and overview.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, Dec. 1985. p. 1-23. Refs., figs. Available from NTIS, Springfield, Va. 22161.

Abstract: This chapter is designed to introduce the subsequent chapters on the state of the art of the potential climatic effects of the increasing atmospheric CO2 concentration and the effects of release into the atmosphere of other trace gases. A definition of weather and climate, an overview of the climate system including its components and processes, and the climatic record are presented as background. An overview of means of projecting climate is presented, in which are considered mathematical models of the climate system and the use of past climate to understand current and future climate by verifying climatic models and to develop analogs of conditions that could be expected in the future. In this regard, the hypsithermal (8000-4000 yr B.P.) and the climate of the past 100 yr are described. The remaining chapters deal with the role of CO2 and other gases in the solar and terrestrial radiation balance; the use of the results of the major modelling studies to investigate the equilibrium sensitivity of climate to relative large changes in CO2 concentration; a review of the efforts made hitherto to study directly the climatic response to increasing CO2 concentration; the potential climatic effects of perturbation of climate by trace gases other than CO2 ; and the information that past climate provides about a warmer world.

43. MacCracken, M. C.; F. M. (eds.) Luther. Lawrence Livermore Natl. Lab., Livermore, CA.
Potential climate effects of increasing carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, Dec. 1985. 381 p. Refs., figs., Tables. Available from NTIS, Springfield, Va. 22161.

Abstract: This publication is the result of a major effort to review the current state of understanding concerning the potential effects and impacts of the increasing carbon dioxide concentration in the atmosphere. The contents include papers by different authors on the problem of CO SUB 2 and climate change; radiative effects of CO2 and trace gases; modelling as a means of studying climate change; model projections of the equilibrium climatic response to increased CO2 ; model projections of time-dependent response to increasing CO2 ; potential climatic effects of perturbations other than CO2 ; implications of past climates for a warmer world; recommendations for research modelling activities for projecting the climatic effects of CO2 ; the analysis of results from energy balance and radiative-convective models; a review of the recent CO2 - climate controversy; and steps to a solution of the problem of estimating the reliability of climate model projections.

44. Manabe, S.; R. T. Wetherald. Geophys. Fluid Dynamics Lab./NOAA, Princeton, N.J.
Reduction in summer soil wetness induced by an increase in atmospheric carbon dioxide.
Science, Wash., D.C., 232(4759): 626-628, May 2, 1986. Refs.

Abstract: The geographic distribution of the change in soil wetness in response to an increase in atmospheric carbon dioxide was investigated by using a mathematical model of climate. By responding to the increase in carbon dioxide, soil moisture in the model would be reduced in summer over extensive regions of the middle and high latitudes, such as the North American Great Plains, western Europe, northern Canada, and Siberia. These results were obtained from the model with predicted cloud cover and are qualitatively similar to the results from several numerical experiments conducted earlier with prescribed cloud cover.

45. Meszaros, E. Inst. for Atmos. Phys., Budapest, Hungary.
On the climate effects of radiatively active trace gases and aerosol particles.
Idojaras, Budapest, 89(2): 70-76, March/April 1985. Refs. English and Hungarian summaries.

Abstract: The sources and sinks as well as the concentration variations of nitrous oxide, methane, chlorofluoromethanes, and ozone in the atmosphere are evaluated. The climatic effects of their concentration variations resulting from human activities are estimated and compared with the modifications possibly caused by the increasing atmospheric level of carbon dioxide. The characteristics of atmospheric aerosol particles are also presented, and their role in the control of climate is briefly discussed.

46. Midot, S. Serv. des Etudes Economiques Generales, Dept.Prospective-Environ.-Communication-Electricite de France.
Les effets du CO2 sur le climat: un bilan des connaissances actuelles. [CO2 effects on climate: balance sheet of current understanding.]
Pollution Atmospherique, Paris, 29(115): 199-225, July/Sept. 1987. Refs., figs. English and French summaries.

Abstract: Atmospheric levels of carbon dioxide (CO2) have strongly increased since the beginning of the 20th century. CO2 concentration doubling before the year 2100 is feared, according to fossil fuel world-burning projections. Resulting climate warming appears to be one of the most acute ecological concerns in the future. This article describes different studies dealing with that topic: phenomena determining the evolution of CO2 atmospheric levels and climate; carbon cycle and climate models used for the predictions; climate changes that might occur; and remedial actions to reduce atmospheric CO2 levels. Conclusions that could be drawn from most recent studies are still subject to considerable uncertainties. An important international research program to understand the related phenomena better and to improve the predictions is under way.

47. Mika, J. Kozponti Legkorfiz. Intezet, Budapest.
A meteorologiai elemek evi menetenek felhasznalasa a globalis klimavaltozas regionalis sajatossegainak becslesere. [Application of the annual cycle of meteorological elements to estimate the regional properties of global climate change.]
Idojaras, Budapest, 91(1): 34-42, Jan./Feb. 1987. Refs., tables. English and Hungarian summaries.

Abstract: The annual cycle of the meteorological elements derived from climatological monthly mean values is applied as an analog to

climate change caused by the probable intensification of the greenhouse effect in the atmosphere. The 22 groups consisting of four different months approximately fulfilling the thermal equilibrium of the atmosphere and the absence of definite direction of ocean-atmosphere heat exchange make the estimation of regional properties in the Carpathian Basin possible in the case of a global climate change as great as PLUS OR MINUS 2K. The local characteristics of temperature, relative humidity, and cloudiness follow the hemispheric changes by a linear law in a good approximation. The zonal changes of temperature in the entire hemisphere and the changes of cloudiness in the high and tropical latitudes show a linear dependence upon hemispheric mean temperature with a positive sign in the regression coefficients, although between 30 and 40° lat., an increase in the mean hemispheric temperature corresponds to a decrease in cloudiness. By this method, the precipitation in the Carpathian Basin follows a special function with more possible values as the mean hemispheric temperature changes. This varied modal behavior of the precipitation is confirmed by the frequency histogram of the real yearly means of precipitation.

48. Mitchell, J. M., Jr. Environ. Data Serv., NOAA, Silver Spring, MD.
Some considerations of climatic variability in the context of future CO_2 effects on global scale climate.
In: Workshop on the Global Effects of Carbon Dioxide from Fossil Fuels, Miami Beach, Fl., March 7-11, 1977, Carbon Dioxide Effects Research and Assessment Program. United States. Dept. of Energy, Office of Health and Environmental Research, Wash., D.C., p. 91-99, May 1979. Refs., figs. Available from NTIS, Springfield, Va. 22161. (Conf-770385, UC-11),

Abstract: Aspects of past variations of planetary-scale temperature conditions on the Earth, which may be helpful in assessing the importance of future climatic changes possibly related to atmospheric CO_2 increases, are considered. The discussion includes a summary of current knowledge on global-scale conditions of temperature for the past 850,000 yr, recent global cooling since 1940 on a worldwide scale, changes in climatic variability and their role in climatic change, and the prospects of climatic change in the near and distant future. The indefiniteness of knowledge on the nature and consequences of and possible responses to climatic change are noted.

49. Mitchell, J. F. B.; C. A. Wilson; W. M. Cunnington. Met. Off., Bracknell.
On CO_2 climate sensitivity and model dependence of results.
Royal Meteorological Society, Bracknell, Eng., Quarterly Journal, 113(475): 293-322, Jan. 1987. Refs., figs., tables, appendix.

Abstract: The regional response of climate models to small perturbations is shown to be highly dependent upon the unperturbed simulation. An experiment in which CO_2 concentrations are doubled and sea surface temperatures are enhanced by 2 K has been conducted with two general circulation models that differ considerably in their control climates. The resulting changes in tropical precipitation in each model simulation are related to the increase in atmospheric water vapor, which leads to enhanced precipitation in the main regions of low- level atmospheric convergence. Because these regions of convergence occur in slightly different locations in the unperturbed simulations, the distribution of changes is also different. Differences in control simulations must be considered when comparing results from different models (e.g., on doubling atmospheric CO_2); otherwise, unduly pessimistic conclusions may be reached concerning the consistency of model results. It may be possible to make subjective allowance for the effect of known deficiencies in the unperturbed simulation on the model's response before using the simulated changes in, for example, impact studies. An examination of one of the experiments reveals that the change in precipitation is limited by the heat balance of the atmosphere and indicates the importance of treating accurately the radiative perturbation resulting from changes in water vapor. The magnitude of the model's response is shown to be consistent with that found in three-dimensional climate models that include a simple representation of the ocean.

50. Moore, B. I.; B. Bolin. Univ. of Stockholm.
Oceans, carbon dioxide, and global climate change.
Oceanus, Woods Hole, MA., Special Issue, 29(4): 9-15. Winter 1986/87.

Abstract: This paper presents a nontechnical, concise overview with the aid of diagrams of current knowledge on the interaction of the oceans, the carbon cycle, and the concentration of CO_2 in the atmosphere in the process of climate change. There are reviewed the evidence of the increasing concentration of CO_2 in the atmosphere; the problem of the imbalances of the annual carbon budget as indicated in input of CO_2 in the atmosphere and uptake of CO_2 by the atmospheric increase, oceanic uptake, and fertilization effects; the role of the oceans in the uptake of CO_2 , including the biological and chemical processes; and the role of the ocean as a sink for excess CO_2 .

51. Oerlemans, J. Inst. of Met. and Ocean., Univ. of Utrecht, Netherlands.
Glaciers as indicators of a carbon dioxide warming.
Nature, London, 320(6063): 607-609, April 17, 1986. Refs., figs,

Abstract: During the past 150 yr, mountain glaciers have shown a worldwide retreat. It has been argued that this is related to the warming that is predicted to result from increased carbon dioxide levels in the atmosphere; however, this warming has not been detected in a statistically significant way from instrumental records. The author demonstrates that the lower part of a valley glacier is extremely sensitive to a local warming, induced by an increase in the radiation budget. For glaciers covering only a small fraction of a valley, the effect is particularly dramatic. Thus, valley glaciers may be extremely vulnerable to the presence of IR-absorbing gases in the atmosphere and could, therefore, be better detectors of a possible carbon dioxide warming than is generally assumed.

52. Parkinson, C. L.
Sea ice as a potential early indicator of climate change.
North American Conference on Preparing for Climate Change, 1st: A Cooperative Approach, Wash., D.C., Oct. 27-29, 1987, Proceedings. Rockville, MD., Government Institutes, Incorporated, p. 118-124, April 1988.

Abstract: After reviewing the areal extent of sea ice distribution over the course of 1 yr and its high concentration in Antarctica, the importance of such extensive sea ice cover to the global climate system, and the probability that changes in the sea ice cover could prove to be early indicators of climate change, are discussed. The following three criteria for a potential early indicator of climate change are listed: the variable should exhibit a large climate signal; it should be readily measurable through routine observations; and it should have low enough natural variability to permit a climate signal to be detected.

53. Rampino, M. R. (ed.). N.Y. Univ.
Climate: history, periodicity, and predictability.
N.Y.: Van Nostrand Reinhold Co., Incorporated, 588 p., 1987.

Abstract: This book contains papers presented at a conference on climate held during May 21-23, 1984, at Barnard College .(Columbia University) in New York City. The papers include new data ranging from recent atmospheric temperature to geologic evidence extending back several billion years. Some are devoted to sophisticated computer modelling and time series analyses. Discussions deal with causal mechanisms for climate change ranging from the purely terrestrial to those involving the Sun, the Moon, the dynamics of the solar system, and even the rhythms of the galaxy. Major emphasis is on climate cycles and the possibilities for predicting the trend of future climate. The papers are grouped under the subjects of 1) historical climate change; 2) proxy climate indicators; 3) sea level change and climate; 4) short-term climate (10-10 SUPER 2 yr) and periodicity; 5) long-term climate (10 SUPER 3 -10 SUPER 7) and periodicity; 6) solar variations, cycles, and possible causes. A selected bibliography on Sun-Earth relationships and cycles having periods of <10,000 yr is included.

54. Rind, D. Goddard Space Flt. Ctr., Inst. for Space Studies, N.Y.
Dependence of warm and cold climate depiction on climate model resolution.
Journal of Climate, Boston, 1(10): 965-997, Oct. 1988.

Abstract: Climate model results are being used to assess the potential societal impact of climate change and to compare with paleoclimate indicators. The models for these purposes currently use relatively coarse resolution, and a key question is how the results might change as resolution is improved. To examine this issue, doubled CO2 and ice age simulations with boundary conditions identical for two different resolutions are run with the GISS model. The resolution dependency of climate change sensitivity, atmospheric dynamics, and regional climate depiction is discussed. The results show that model resolution affects two key processes in the control runs, moist convection and the nonlinear transfer of kinetic energy into the zonal mean flow. The finer resolution model has more penetrative convection but less convection overall, aspects that alter its temperature and wind structure relative to those of the coarser grid model. With finer resolution, there are also stronger winds, more evaporation, and a more active hydrologic cycle. While some of these changes are not particularly large, their characteristics are mirrored in the warm and cold climate simulations. In comParison with the coarser resolution model, the finer grid doubled CO2 run has a greater decrease in high-level cloud cover, eddy energy, and eddy energy transports and a greater increase in atmospheric temperature, surface winds, precipitation, and penetrative convection. The ice age finer grid run shows the opposite effects when compared with the medium grid: greater eddy energy and eddy transport increases, greater reduction in the hydrologic cycle and atmospheric temperature. Regional climate changes also differ with resolution, because of the local expression of the different dynamical responses and the differing spatial possibilities. The development of higher resolution models and the practical use of climate change results should incorporate an awareness of the potential impact of resolution on model processes and climate change depiction.

55. Rind, D. Goddard Space Flt. Ctr., Inst. for Space Studies, N.Y.
Doubled CO SUB 2 climate: impact of the sea surface temperature gradient.
Journal of the Atmospheric Sciences, Boston, 44(21): 3235-3268, Nov. 1, 1987.

Abstract: Even though five different general circulation models are all currently producing an APPROX. 4 PLUS OR MINUS 1°C warming for doubled CO2 , there is still substantial model disagreement concerning the degree of high-latitude amplification of the surface temperature change. The consequences of this disagreement are investigated by comparing doubled CO SUB 2 climates with different latitudinal gradients of sea surface temperature. The GISS 4 MULTIPLIED BY 5° general circulation model (GCM) was run with doubled CO2 and two sets of sea surface temperatures: one set derived from the equilibrium doubled CO SUB 2 run of the 8 MULTIPLIED BY 10° GISS GCM, with minimal high-latitude amplification; and the other set more closely resembling the GFDL results, with greater amplification. While the experiments differ in their latitudinal distribution of warming, they have the same global mean surface air temperature change. The differences in energy balance, atmospheric dynamics, and regional climate simulations are discussed. The results show that the two experiments often produce substantially different climate characteristics. With reduced high-latitude amplification and, thus, more equatorial warming, there is a greater increase in specific humidity and the greenhouse capacity (the concentration of IR-absorbing gases) of the atmosphere, resulting in a warmer atmosphere in general. Features such as the low-latitude precipitation, Hadley cell intensity, jet stream magnitude, and atmospheric energy transports all increase compared with the control run. In contrast, these features all decrease in the experiment with greater high-latitude amplification. There are also significant differences in the cloud cover and stationary eddy energy responses between the two experiments, as well as most regional climate changes; i.e., there is greater drying of the midlatitude summer continents and greater polar ice melting when the high-latitude amplification is greater. Predictions of the coming doubled CO2 climate and its societal consequences must be tempered by the current uncertainty in the degree of high-latitude amplification.

56. Roger, T. C. Inst. Marine Sci., Univ. Alaska-Fairbanks.
Upper ocean temperature variability in the Northeast Pacific Ocean: is it an indicator of global warming?
Journal of Geophysical Research, Washington, D.C., 94(C12): 18, 175-18,183, Dec. 15, 1989.

Abstract: The upper waters of the Northeast Pacific Ocean contain very low frequency temperature fluctuations which have amplitudes of more than 1 degree Celsius. Hydrographic measurements are used to examine these variations. The very low frequency (VLF) 20- to 30- year fluctuation in SST found at and north of 55 degrees N is not evident at lower latitudes. This VLF fluctuation exists throughout the water column on the shelf of the northern Gulf of Alaska. Contained within the hydrographic data on the shelf are responses to El Nino-Southern Oscillation (ENSO) forcing. However, ENSO responses are not evident in the SST data. The propagation characteristics of SST anomalies through the region are not consistent from one event to another. Correlations with local wind stress and wind stress curl are very poor, implying that the temperature variaibility is not wind forced. The causes for these temperature anomalies are uncertain. Though climate changes due to increases in greenhouse gases might be amplified at high latitudes, heating due to gloabl warming is discounted. Coupling of the temperature fluctuations with solar activity and lunar tides is possible especially at high latitudes and the periods of the temperatures, tides, and solar activity are well matched. In any case, the recent upper ocean warming is probably not a result of large-scale global change but is, rather, part of the VLF zonal signal. Below normal water and air temperatures should occur over the next 5-15 years. This VLF signal must be considered and understood before we will be able to measure the effects of high-latitude climate changes.

57. Sarmiento, J. L. Geophys. Fluid Dynamics Program, Princeton Univ., N.J.
Three-dimensional ocean models for predicting the distribution of CO2 between the ocean and atmosphere.
In: Trabalka, John R.; Reichle, David E. (eds.), Changing Carbon Cycle: a Global Analysis. N.Y., Springer-Verlag, Incorporated, p. 279-294, 1986.

Abstract: The basic ingredients necessary to predict fossil fuel CO_2 uptake with a three-dimensional model are discussed: specification of boundary conditions at the air-sea interface for the entire period of prediction, a model of the interior physical processes of advection and mixing, and a model of the biological and chemical processes affecting the carbon cycle. In view of the still-unrealistic nature of three-dimensional models, the author observes that the major application of three-dimensional models should be as a form of laboratory where analog modelling can be tested and the effects of chemical and biological processes on the CO_2 uptake can be studied. Some results of research conducted by the author during the Geophysical Fluid Dynamics Program are reviewed: the features of the free thermocline tritium model of Sarmiento and Bryan (1982), including a listing of the equations and parameters, and results of tritium simulation for studying ocean circulation; a review of studies involving the application of the analog modelling approach to tritium simulation to investigate ocean uptake of fossil fuel CO_2 ; and the role of the oceanic biosphere in fossil fuel uptake.

58. Schlesinger, M. E. OR. State Univ.
Analysis of results from energy balance and radiative-convective models.
United States. Dept. of Energy, Office of Basic Energy Sciences, Wash., D.C., DOE/ER-0237, Dec. 1985. Appendix A, p. 281-319.

Abstract: The general formulation of energy balance models (EBMs) for predicted change in the temperature at the Earth's surface, induced by an increase in CO_2 concentration, is set forth in this highly mathematical paper, whereby it is shown that the determination of temperature change induced by an increase in CO_2 concentration requires knowledge of the associated thermal forcing, the zero feedback gain of the climate system, and the feedback. These, in turn, require knowledge of the partial derivatives of net energy flux with regard to CO_2 concentration, the temperature, and the internal quantities, as well as the total derivative of the internal quantities with regard to temperature. From this point of view, the surface energy balance models are examined, including the results of calculations of CO_2 induced warming by Callendar (1938), Moller (1963), and Newell and Dopplick (1973); and the formulation of planetary energy balance models is presented. The formulation of radiative-convective models is presented, and analysis and interpretation of the results of their application are reviewed: e.g., direct radiative forcing due to increased CO_2 ; response of the climate system without feedback to increased CO_2 ; response of the climate system with feedback to increased CO_2 (surface energy flux, water vapor feedback, temperature lapse rate feedback, cloud altitude feedback, cloud cover feedback, cloud optical depth feedback, and surface albedo feedback).

59. Schlesinger, M. E. Climatic Res. Inst., OR. State Univ., Corvallis.
Climate model simulations of CO_2 -induced climatic change.
In: Advances in Geophysics, Vol. 6., p. 141-235 Orlando, Fl.: Academic Press, Inc., 1984.

Abstract: The current issues attending the physical method for investigating CO_2 -induced climatic change are formulated and described. Various mathematical climate models are described qualitatively: energy balance models, radiative-convective models, and general circulation models. Model simulations of CO_2 -induced climatic change are compared by considering descriptions of GCMs and CO_2 simulations, and simulated temperature, precipitation, and soil moisture changes. Topics discussed are model-dependent results, the time required to reach equilibrium, and the statistical significance of changes in surface air temperature, precipitation rate, and soil moisture simulated by the Oregon State University (OSU) two-level general atmospheric model.

60. Schlesinger, M. E.; J. F. B. Mitchell. OR. State Univ.; Great Britain, Met. Off.
Model projections of the equilibrium climatic response to increased carbon dioxide.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D:C., DOE/ER- 0237, p. 81-147, Dec. 1985.

Abstract: The modelling methods and results of major modelling designed to investigate the equilibrium of the sensitivity to relative large changes in atmospheric CO_2 concentration are described. Simplified climate models are presented for assessing the potential climate effect of CO_2 concentration involving energy balance models and radiative-convective models, the computational equations, and some results of their application. Studies of CO_2 -induced equilibrium climate change conducted with general circulation models with several different treatments of the ocean and sea and ice are reviewed. These studies involve simulations without the annual insolation cycle (changes in zonal mean air temperature, changes in precipitation and soil moisture, and changes in cloud cover); early simulations with the annual insolation cycle (studies with prescribed sea surface temperature and sea ice extent, and studies with predicted sea surface temperature and sea ice extent); the dependence of CO SUB 2 -induced climate change upon the control climate; and recent simulation with the annual insolation cycle (comParison of the simulated and observed 1 MULTIPLIED BY CO_2 climates (simulated by Goddard Institute for Space Studies (GISS), National Center for Atmospheric Research (NCAR), and Geophysical Fluid Dynamics Laboratory (GFDL) models with predicted clouds); comParison of recent simulations of 2 MULTIPLIED BY CO - 1 MULTIPLIED BY CO climate changes simulated by the GISS, NCAR and GFDL models; and feedback analysis. A series of recommendations are set forth for further understanding the differences and similarities of the most recent simulations and for developing more comprehensive models of the climate system.

61. Schneider, S. H.
Climate modeling.
Scientific American, N.Y., 256(5):72-80, May 1987.

Abstract: The processes that make up our climate are too complex to be reproduced physically in the laboratory. Fortunately, they can be simulated mathematically with the help of a computer. Mathematical climate models cannot simulate the full complexity of reality. However, they can reveal the logical consequences of plausible assumptions about the climate. Climate models vary in the number of dimensions they simulate and the amount of spatial detail they include. Computer models of the earth's climate yield clues to its future as well as to its past.

62. Schneider, S. H.
Climate modeling.
Spektrum Wiss. (Germany, Federal Republic of), 7:52-59, Jul 1987.

Abstract: Will the 'greenhouse effect' bring on another Dust Bowl. Would nuclear war mean 'nuclear winter'. Computer models of the earth's climate yield clues to its future as well as to its checkered past.

63. Solomon, A. M. Environ. Sci. Div., Oak Ridge Natl. Lab., TN.
Global cycle of carbon.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0239, p. 11-13, Dec. 1985, Refs., figs. Available from NTIS, Springfield, Va. 22161.

Abstract: This chapter outlines the nature of the carbon dioxide (CO2) question and the general role of the global carbon cycle in regulating the amount of CO2 in the atmosphere. The scientific and societal issues that result from interactions between changing CO2 emissions and the global cycle processes are then described. The CO SUB 2 question is examined in light of its climatic, indirect, and vegetation effects. In regard to the global carbon cycle, discussions are included on the current global atmospheric total of carbon reflecting a significant increase resulting from accelerated burning of fossil fuels, and the unaccounted fraction of CO2 in calculated uptake by ocean and atmosphere; the CO2 exchanges between ocean and atmosphere; the terrestrial biosphere as carbon source and sink; and fluxes between the global reservoirs. The scientific and social issues of the CO2 problem are surveyed.

64. Somerville, R. C. J. Scripps Inst. of Ocean., Univ. of CA., San Diego.
Cloud optical thickness feedbacks in the CO2 climate problem.
Advances in Space Research, Oxford, Pergamon Press, Vol. 5, No. 6, p. 209-212, 1985. Refs. (Symposium 4 of the COSPAR Twenty-fifth Plenary meeting held in Graz, Austria, June 25-July 7, 1984, Proceedings).

Abstract: A radiative-convective equilibrium model is developed and applied to study cloud optical thickness feedbacks in the CO2 climate problem. The basic hypothesis is that, in the warmer and moister CO SUB 2 -rich atmosphere, cloud liquid water content will generally be larger than at present so that cloud optical thickness will also be larger. For clouds other than thin cirrus, the result is to increase the albedo more than to increase the greenhouse effect. Therefore, the sign of the feedback is negative: cloud optical properties alter in such a way as to reduce the surface and tropospheric warming caused by the addition of CO2 . This negative feedback can be substantial. When observational estimates of the temperature dependence of cloud liquid water content are used in the model, the surface temperature change caused by doubling CO2 is reduced by approximately one half.

65. Somerville, R. C. J.; L. A. Remer. Scripps Inst. of Ocean., Univ. of CA., San Diego.
Cloud optical thickness feedbacks in the CO2 climate problem.
Journal of Geophysical Research, Wash., D.C., 89(D6): 9668-9672, Oct. 20, 1984. refs.,

Abstract: A radiative-convective equilibrium model is developed and applied to study cloud optical thickness feedbacks in the CO2 climate problem. The basic hypothesis is that, in the warmer and moister CO SUB 2 -rich atmosphere, cloud liquid water content will generally be larger also. For clouds other than thin cirrus, the result is to increase the albedo more than to increase the greenhouse effect. Thus, the sign of the feedback is negative: cloud optical properties act as a thermostat and alter in such a way as to reduce the surface and tropospheric warming caused by the addition of CO2 . This negative feedback can be substantial. When observational estimates of the temperature dependence of cloud liquid water content are used in the model, the surface temperature change caused by doubling CO2 is reduced by approximately one half. This result is obtained for global and annual average conditions, no change in cloud amount or altitude, and constant relative humidity. These idealizations, with other simplifications typical of one-dimensional radiative- convective climate models, render the result tentative. Additional study of cloud optical property feedbacks is warranted, however, because the climate is apparently so sensitive to them.

66. Stolarski, R. S.
Antarctic ozone hole.
Scientific American, N.Y., 258(1): 30-36, Jan. 1988.

Abstract: A review is given of the recent findings of ozone depletion over the South Pole region and the role of chlorofluorocarbons (CFCs) as a cause of the depletion. Chemical processes are described to show how the CFCs react on ozone to attenuate the shield over Antarctica. Some of the effects of the depletion on people and environments are discussed. A possible role is projected of polar stratospheric clouds as transformers of chlorine reservoirs into active chlorine to react unfavorably with the ozone as the Sun begins to shine again after the dark Antarctic winter. A dynamical mechanism as a factor in the process is also a possibility.

67. Trabalka, J. R. Environ. Sci. Div., Oak Ridge Natl. Lab., TN.
Human alterations of the global carbon cycle and the projected future.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 2039, p. 247-287, Dec. 1985. Refs., figs. available from NTIS, Springfield, Va. 22161.

Abstract: An attempt is made to project the level of carbon dioxide in the atmosphere over the next century (to the year 2075) to establish probable significant climatic and biological consequences of accelerated fossil fuel combustion. The following topics are summarized: the current state of knowledge on the contemporary atmospheric CO2 concentration; historical fossil fuel releases; historical atmospheric CO2 concentrations; the history of the terrestrial biospheric flux of CO2 and the uncertainties in the record; the role of the oceans as the principal sink of CO2 ; the missing sinks that are required to balance the CO2 cycle; the effective airborne fraction of CO2 ; potential roadblocks to improved understanding of the CO2 cycle resulting from difficulties of estimating CO2 sources and sinks; and the various difficulties of modelling, such as incorporation of deep water injection in assessing climatic response to water freshening, changes in global carbon storage, etc. With regard to the future of atmospheric CO2 emissions, the following discussions are presented: 1) fossil fuel CO2 emissions involving development of reference projections and comParisons with other estimates of future CO2 emissions; 2) terrestrial biospheric CO2 releases, including effects of CO SUB 2 fertilization, effects of climatic change, air pollution stresses, and land- use conversion combined with other factors; 3) methods for projecting future atmospheric CO2 levels; 4) reference projections with globally averaged carbon cycle models; 5) carbon cycle uncertainty analysis, including sensitivity studies and Monte Carlo studies; and 6) uncertainties in atmospheric CO2 projections, i.e., reference projections and comParisons with other atmospheric CO2 projection exercises.

68. Trabalka, J. R.; D. E. Reichle (Eds). Environ. Sci. Div., Oak Ridge Natl. Lab., TN.
Changing carbon cycle: a global analysis.
Selected papers from the proceedings of the Sixth Annual Oak Ridge National Laboratory Life Sciences Symposium, held Oct. 31-Nov. 2, 1983 in Knoxville, TN
N.Y.: Springer-Verlag Incorporated, 592 p., 1986.

Abstract: This volume constitutes a selection of papers presented at the symposium. The topics covered include 1) the atmospheric concentrations of CO2 , beginning with the most recent patterns of increases and progressing backward in time; 2) the methodological aspects of the use of analytical techniques and the interpretation of ratios of carbon isotopes in tree rings and geologic media laid down in past centuries to estimate historic concentrations of CO2 and to identify sources both fossil and biological; 3) terrestrial biota and soils as reservoirs of carbon active in the global cycle, involving historical changes in the carbon pool represented by terrestrial vegetation, the manner in which soil carbon changes through time in response to disturbance and recovery of the vegetation cover, and evaluation of the potential of remote sensing to measure current changes in land cover on a continental and global scale; 4) carbon cycles in the ocean, including their modelling and a summary of recent empirical measurements of CO2 and alkalinity in ocean waters; 5) the synthesis of the scientific information presented and its application to understanding the role of anthropogenic emissions of CO2 in the atmosphere in changing the global carbon cycle, whereby there are discussed the value and limitations of using geologic analogs in carbon cycle research and modelling, the requirements for a satisfactory model representation of the global cycle, the calibration of such models and their validation by observed data, and the manner in which the seasonal and geographic patterns of CO2 provide information on the current global carbon balance; 6) fossil fuel sources of anthropogenic CO SUB 2 emissions into the atmosphere as manifested in recent history, current patterns, and possible future trends, and the important variables of fossil fuel reserves and future energy production options; the use of globally averaged carbon cycle models in conjunction with model projections of future use and CO2 emissions to estimate the likely bounds of future atmospheric CO2 concentrations; and 7) technological choices that might limit the increase of future atmospheric CO2 levels and the potential confounding effects of other radiatively active trace gases on such surfaces.

69. Verbitskiy, M. Y.; D. V. Chalikov. Leningradskiy Otdel. Inst. Okean. im. P. P. Shirshova, Akad. Nauk, U.S.S.R.
Model' klimata Mirovogo okeana. [Model of the world ocean climate.]
Okeanologiya, Moscow, 26(3): 357-364, May/June 1986. Refs. English and Russian summaries. Transl. into English in corresponding issue of Oceanology, Wash., D. C.

Abstract: A thermohydrodynamic model, which takes into consideration the real morphology of the world ocean and simulates the long-period climate evolution in the framework of an ocean-atmosphere-ice system, is proposed. The present climate of the ocean (thermal regime, heat exchange with atmosphere, meridional heat, and mass fluxes) is calculated. The sensitivity of the model to changes in several parameters is investigated.

70. Wang, W.-C. Atmos. and Environ. Res., Inc., Cambridge, MA.
Climatological effects of atmospheric ozone: a review.
Ozone Symposium, 4th, Halkidiki, Greece, Sep. 3-7, 1984, Atmospheric Ozone: Proceedings. Dordrecht, Reidel Publ. Company, p. 98-102, 1985.

Abstract: The results of studies on the climatological effects of atmospheric ozone are reviewed: the O SUB 3 direct radiative effect, the climatic effect of O SUB 3 redistribution, and tropospheric O SUB 3 . The most important aspect is probably the change in O SUB 3 distribution (especially around the tropopause region) associated with anthropogenic activities. The O SUB 3 distribution is influenced by chemistry and transport processes and perhaps introduces the largest uncertainties in the model-calculated O SUB 3 climatological effect.

71. Wang, W.-C.; G. Molnar. Atmos. and Environ. Res., Inc., Cambridge, MA. **Model study of the greenhouse effects due to increasing atmospheric CH SUB 4 , N2O, CF SUB 2 Cl SUB 2 , and CFCl SUB 3.**
Journal of Geophysical Research, Wash., D.C., 90(D7): 12971-12980, Dec. 20, 1985.

Abstract: Study of the greenhouse effects of increasing atmospheric trace gases relied mainly on the use of one-dimensional models, especially the radiative-convective models (of the World Meteorological Organization, 1982; National Research Council, 1983). The authors use the two-dimensinoal (altitude-latitude) radiative-dynamical model of Wang et al. (1984) to investigate the effects on vertical and meridional temperatures of increases of atmospheric methane, nitrous oxide, and chlorofluorocarbons. The model, consisting of a high- and a low-latitude zone, couples the meridional and vertical temperature structure through energy balance between radiative flux and vertical and meridional heat transports. The thermal radiation flux perturbations, i.e., the driving force for the subsequent climate change, caused by increases of these trace gases and carbon dioxide, are different in nature. A comParison of model-calculated present climate and climate change between the one- and two-dimensional models is performed. The results indicate that the two-dimensional model simulates more realistic temperature and humidity distributions. For a doubling of the atmospheric CO2 concentration of 330 p.p.m.v., the two-dimensional model computes a global surface warming of 3.7 K with larger high-latitude amplification, which is in good agreement with results obtained from general circulation models. For the study of the surface warming caused by increases of trace gases, it is found that the one-dimensional model using a 6.5-K km SUPER - SUPER 1 critical lapse rate for convective adjustment appears to calculate a much larger surface warming than the two-dimensional model. Conversely, the one-dimensional model using the moist adiabatic critical lapse rate, although it cannot simulate adequately the present tropospheric temperature structure, calculates surface warming effects in close agreement with those of two-dimensional model results. The two-dimensional model is used to estimate on the time scale of decades the potential greenhouse effects caused by increases of these gases. Although the calculations depend largely upon the adopted scenarios for future increases, the results nevertheless reveal that the trace gases could potentially augment the surface warming due to carbon dioxide increase by >60%.

72. Webb, T. I.; T. M. L. Wigley. Brown Univ., Providence, R.I.; Univ. of E. Anglia, Norwich, Eng.
What past climates can indicate about a warmer world.
United States. Dept. of Energy, Office of Energy Research, Office of Basic Energy Sciences, Wash., D.C., DOE/ER- 0237, p. 237-257, Dec. 1985. Refs., figs. available from NTIS, Springfield, Va. 22161.

Abstract: The perspective of past climate changes as a means of evaluating the probable validity of theoretical models and, in a limited sense, of projected climate changes is examined. As a background for the discussion, the authors review the possible role of CO2 in past climatic changes, the development and features of climate scenarios, and model validation with paleoclimatic data. Climatic scenarios based on instrumental data are then described whereby the assumptions, principles, and observational evidence involved in developing climate scenarios are discussed and the procedures of climate construction are described. The program of mapping the climate patterns at 6000 yr B.P. with the aims of 1) assessing a global set of paleoclimatic data for this time period, 2) studying certain of the regional climatic implications of a rise in the global mean temperature, and 3) obtaining average temperature estimates for regions, continents, and even the globe, to show how the temperature has varied between 6000 yr B.P. and now, has been under way for

some time. In connection with this program, the authors discuss the data and analysis; regional climate estimates, including temperature estimates for eastern North America and Europe, sea surface temperature estimates, precipitation estimates for the American Midwest, and global estimates and lake levels; whether the Earth was warmer than today at 6000 yr B.P.; and climate model validation.

73. Wigley, T. M. L. Natl. Ctr. for Atmos. Res., Boulder, CO.
Effect of model structure on projections of greenhouse-gas-induced climatic change.
Geophysical Research Letters, Wash., D.C., 14(11): 1135-1138, Nov. 1987.

Abstract: The transient response of global mean temperature to greenhouse-gas forcing between A.D. 1765 and 2030 is studied by using two types of ocean models, a pure diffusion model and an upwelling-diffusion model. The results are almost the same for both types of model. If the greenhouse-gas contribution to global warming over the period 1880-1985 is DELTA , then the contribution to future warming over the period 1985-2030 is shown to be APPROX. 1.6 DELTA independent of model type and model parameters (e.g., climate sensitivity and ocean-mixing rate).

74. Wigley, T. M. L.
Relative contributions of different trace gases to the greenhouse effect.
Climate Monitor, Norwich, Eng., 16(1): 14-28, Winter 1987.

Abstract: Up-to-date information on concentrations of trace gases and radiative effects is used to quantify the relative contributions of the various greenhouse gases both in the past and, on the basis of recent projections, in the future to the year 2030. Simple empirical expressions for the past and future concentrations of each trace gas are derived, and what is known concerning past concentrations of the trace gases carbon dioxide, methane, nitrous oxide, and the chlorofluorocarbons is reviewed. The relationship between radiative forcing change at the top of the troposphere and concentration change is examined with empirical equations for CO2 , CH SUB 4 , N2O, and CFCs. By using the equations enabling computation of past and future concentrations of trace gases and of radiative forcing, which enable conversion of the former to radiative forcing, past and possible future forcings for each of the trace gases are calculated, and relative radiative forcing histories are developed. Implications of the results in terms of climate are then discussed. Since the late 19th century and probably through at least 2030, the trace gases CH SUB 4 , N2O, and the CFCs have, together, added 80% to the radiative forcing resulting from increasing atmospheric CO2 concentration. This means that an equivalent doubling of the preindustrial CO2 level could occur well before 2020. Between 1880 and 1985, the radiative forcing caused by anthropogenic greenhouse gas concentration changes was 1.7 Wm SUPER - SUPER 2 . If the climate sensitivity is as implied by recent GCM results, the globe should have warmed by APPROX. 1°C in response to this forcing, even if the damping effect of oceanic thermal inertial is accounted for. The observed warming has only been APPROX. 0.5°C. If this discrepancy implies that there are gross shortcomings in one-dimensional ocean models currently used to study the transient response of the climate system, then there must be a considerable amount of unrealized warming in the climate system. Conversely, if this discrepancy implies an additional factor (or factors) operating on the century time scale and acting to offset the greenhouse gas forcing, or large errors in current GCMs, then there is no obvious reason why, in the future, this factor should not act in the opposite direction and add to, rather than subtract from, the greenhouse effect.

75. Wigley, T. M. L.; P. D. Jones; P. M. Kelley. U. o. E. Anglia, Norwich, Eng. Climatic Res. Unit.
Empirical climate studies: warm world scenarios and the detection of climatic change induced by radiatively active gases.
In: Greenhouse effect, climatic change, and ecosystems, Chichester, Eng., John Wiley & Sons, 1986. Bolin, B. (ed.).

Abstract: A number of empirical approaches to the study of climatic changes induced by radiatively active gases are described. It is noted that empirical studies do not yet distinguish the effects of CO2 from those of other radiatively active trace gases, such as methane, nitrous oxide, ozone, and chlorofluorocarbons. Past climatic changes and fluctuations are reviewed as related to the greenhouse gases problem, namely, CO2 effects on the 10 SUPER 6 -10 SUPER 9 -yr time scale, the 10 SUPER 3 -10 SUPER 5 yr time scale, the interval 6000 B.P. A.D. 1850, and recent climatic change-A.D. 1850 to the present; the latter includes surfact temperature changes, upper air temperature changes, and precipitation changes. The scenario approach to the estimation of future climatic conditions is set forth by discussing analog-based scenario development, including analog scenarios based upon a suitably defined ensemble of warm years from the recent instrumental record and a comparison with either the reconstructions of paleoclimate during postwarm periods; and the use of atmospheric dynamic arguments together with a knowledge of empirical climate relationships and correlations to develop an educated guess. Instrumental scenario construction is described, and the relevance of scenarios is discussed. The detection of climatic change is examined by considering the climatic indicators sought, the signal-to-noise ratio concept, statistical strategies (simple signal-to-noise ratio studies, noise reduction studies, and the fingerprint method); and simple analysis of the recent surface air temperature record. Monitoring requirements are set forth.

76. Wilson, C. A. Dynamical Climatol. Branch, U.K. Met. Off., Bracknell.
2 CO2 climate sensitivity experiment with a global climate model including a simple ocean.
World Climate Research Programme, Geneva, Report No. 9, p. 7.34-7.36, Sep. 1986. Refs., figs. (WMO/TD- No. 141)

Abstract: The sensitivity of global climate to doubled atmospheric CO2 has recently been investigated by using the Meteorological Office's 11-layer general circulation model, with horizontal resolution of 5° MULTIPLIED BY 7.5° coupled to a simple mixed-layer ocean model and a thermodynamic sea-ice model. The ocean depth of 50 m was sufficient to represent the seasonal heat storage. Transport of heat by the oceans was allowed for by specifying a seasonally varying heat convergence which was derived from a previous integration of the model with prescribed sea surface temperatures and ice extents appropriate to present-day climate. This made it possible for the coupled model to simulate well the present climate with sea surface temperatures generally within 2°C of observations and with a realistic seasonal variation of sea ice. When CO2 was doubled, a new equilibrium was reached after 35 yr with global annual mean temperatures warmer by 5.2°C and reduced sea ice cover throughout the year. Cloud cover decreased globally by 3.5% with a general decrease in middle level clouds, increased high cloud, and some increase at low levels at high latitudes. The pattern is similar to that found in other studies (Wetherald and Manabe, 1986) and to the response of the model at a higher resolution (2.5° MULTIPLIED BY 3.75°) with doubled CO2 and a uniform 2 K increase in sea-surface temperatures (Wilson et al, 1985). A detailed investigation of the latter experiment shows that the cloud changes are consistent with rising height of the tropopause because of heating of the troposphere and cooling of the stratosphere with enhanced CO2 . The warming in the coupled model is slightly larger than in other studies elsewhere which included model-generated cloud; this is likely to be partly due to the use of a penetrative convection scheme rather than moist convective adjustment, and to not restricting cloud at upper levels. The distribution of precipitation changes during June-Aug. shows increases at high latitudes and throughout much of the tropical convergence zone and decreases over large parts of northern continents in midlatitudes. There is a tendency for a northward shift of the main precipitation belts with increased monsoon

rainfall over India and East Africa and large decreases over the West Pacific; this is likely to be a response to the increased heating over land because of reduced cloud.

77. Wilson, C. A.; J. F. B. Mitchell. Met. Off., Bracknell, Eng.
Doubled CO SUB 2 climate sensitivity experiment with a global climate model, including a simple ocean.
Journal of Geophysical Research, Wash., D.C., 92(D11): 13315-13343, Nov. 20, 1987.

Abstract: The sensitivity of a global climate model to increased atmospheric CO2 concentrations is presented, assessed, and compared with earlier studies. The ocean is represented by a 50-m slab in which the heat convergence caused by oceanic dynamics is prescribed, producing an accurate simulation of sea surface temperatures, sea ice extents, and associated features in the control simulation. Changes in surface temperature are qualitatively similar to those found in earlier studies using models with similar or lower horizontal resolution, although the global warming is slightly larger. The simulated changes in hydrology agree broadly with those in studies made with higher horizontal resolution and prescribed changes in sea surface temperatures and include a drying over the northern midlatitude continents. Many of the discrepancies in the responses of different models can be traced to differences in the simulations of present-day climate. The choice of convective parameterization appears to influence the sensitivity of the simulated response in the Tropics.

78. Winstanley, D. Natl. Acid Precipitation Assessment Program, Wash., D.C.
Africa in drought: a change of climate?
Weatherwise, Wash., D.C., 38(2): 74-81, April 1985.

Abstract: In the absence of a credible climate prediction capability, the expectations of future climatic conditions must be based on analyses of the historical records. It is shown that such analyses do not support the hypothesis of stable climates in tropical Africa. The evidence of ongoing climatic changes should necessitate a review of the perspectives on climatic conditions in Africa for future decades. As yet, there is no evidence of change in the downward trend in rainfall in the sub-Saharan zone, nor of a peaking of the upward trend farther south. The significance of a continuation of the trends to the welfare of the various African nations and peoples involved seems to deserve serious attention.