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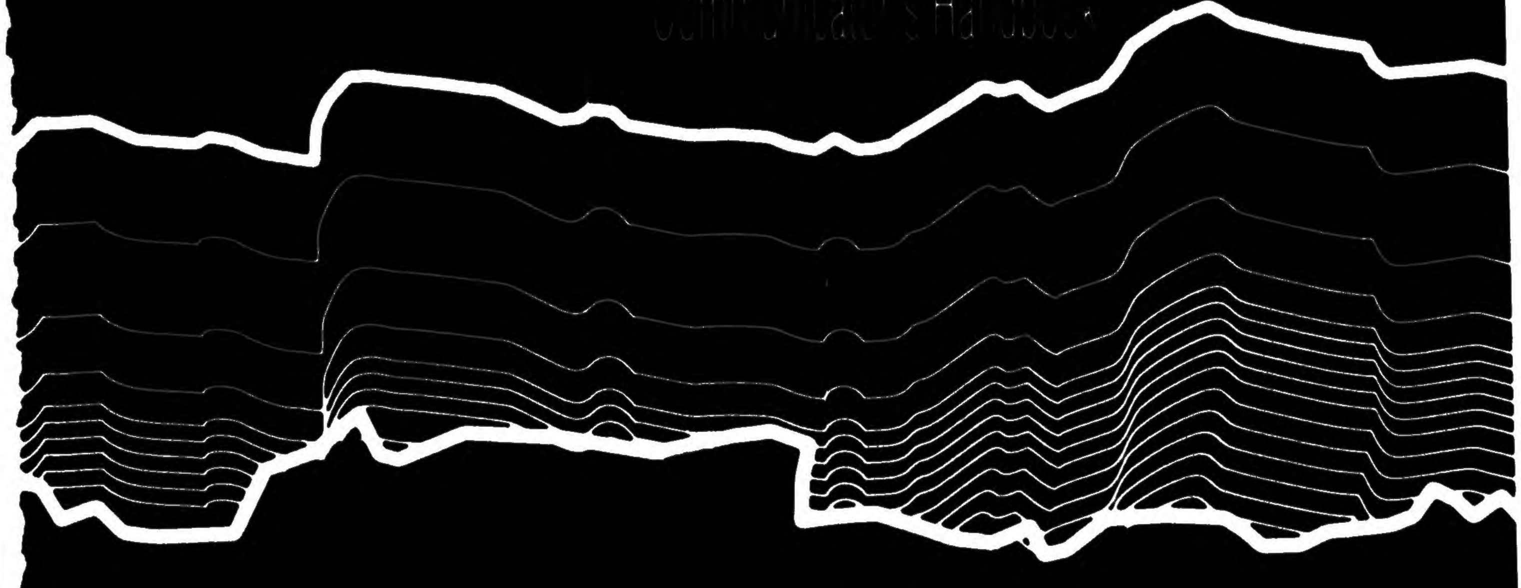
ABSTRACT

As National Park Service (NPS) employees are charged with providing interpretation and education, this manual provides them with a training document and resource guide on the subject of global change. An introduction contains excerpts of the Climate Change Action Plan released in October 1993. Section 2 contains six summaries of technical materials on global change. Section 3 consists of materials that specifically address NPS roles in interpretation and global change. Section 4 contains content materials that may be needed to develop a global change communications program. Twenty fact sheets on related topics were included to provide an overview of the many facets of global change. Section 5 consists of sample global change programs and materials. Each program sheet contains a general program idea designed for a variety of different audiences, interpretive techniques, and park resources. All items are adaptable across media and content. Section 6 offers suggestions for the development of a park's own global change program. Section 7 includes a glossary, book, and article bibliography (87 entries) and a listing of resource materials, teaching aids, and audio-visual resources (60 entries). (LZ)

Interpreting Global Change

A National Park Service Communicator's Handbook



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1.1 Letter of Transmittal

United States Department of the Interior

NATIONAL PARK SERVICE
P.O. Box 37127
Washington, D.C. 20013-7127

IN REPLY REFER TO

Dear Interpreter:

Global change is more than just a passing initiative. It effects all of us and in the future it may have a significant effect on how we live.

National parks will serve as barometers where change can be measured and worldwide prediction can be made.

As National Park Service employees charged with providing interpretation and education, it is important that we avail ourselves with as much information on this subject as possible.

This manual has been provided to you as a training document and resource guide. We hope that you will not just put it on your bookshelf, but rather use it to increase your knowledge of Global Change and increase your ability to share that knowledge with visitors and students.

This is an important topic that will not be going away. Seize the opportunity to learn as much as you can and through your programs share it with others.

Charles W. Mayo
Charles W. Mayo
Chief, Division of Interpretation
National Park Service

Peter Comanor
Peter Comanor
Global Change Research Program
Coordinator
National Biological Survey

Introduction

1.2 Director's Letter

FROM THE DIRECTOR

The distinguished American historian Barbara Tuchman once observed, "A phenomenon noticeable throughout history regardless of place or period is the pursuit by governments of policies contrary to their own interests."

Ms. Tuchman asks, "Why do holders of high office so often act contrary to the way reason points and enlightened self interest suggests? Why does intelligent mental process seem so often not to function?"

Since the preservation of this planet, currently the only one we have, would seem to be in the best interest of everyone, even governments, why is this not the case?

Ms. Tuchman does not directly answer her question in her book, *The March of Folly*; but she does suggest the answer may lie in a shortage of "Askers," large numbers of well-informed people who insist on becoming even more well-informed by constantly and persistently asking pertinent and even embarrassing questions of decision makers.

Global Change will, it is hoped, help educate this multitude of "Askers," those people vitally necessary for the preservation of the environment as well as democracy.

Global Change is not designed to indoctrinate the "Asker" in the "right" solution or the "correct" answer, but to pose challenges, choices, and the consequences of those choices. There are no final solutions, but using the principles laid down in *Interpreting Global Change*, we can help that "intelligent mental process" to function.

Mankind is now a force -- along with wind, water, volcanoes, and continental drift -- in the shaping of our planet and its life. Today's National Park visitors will not see some of the subtle changes that accumulate over generations. Yet, these future changes will be wrought as a result of existing patterns of energy consumption and land use practices. Global Change interpretation provides an excellent opportunity to integrate social, biological, aesthetic, and economic concerns in public education. We need to think far into the future and far beyond park boundaries in order to anticipate and understand changes which are not immediately obvious.

I wish you well in the endeavor of Global Change interpretation. May you produce many generations of "Askers" to guide our decision makers.

Roger G. Kennedy
Director, National Park Service

Introduction

1.3 The President's Climate Change Action Plan — Summary

In October 1993, President William J. Clinton and Vice President Albert Gore, Jr. released The Climate Change Action Plan. Provided within this section are the Preface, Executive Summary and Overview from the President's Action Plan.

PREFACE

Last year (1992) in Rio de Janeiro, Brazil, world leaders and citizens from more than 200 countries came together to confront the global ecological crisis. The Earth Summit aroused the hopes and dreams of people around the world and set in motion ambitious plans to address the planet's deepest environmental threats. We shared a common mission: to provide a higher quality of life for ourselves and a brighter future for our children.

At the Earth Summit, the United States joined other countries in signing the Framework Convention on Climate Change, an international agreement to address the danger of global climate change. The Convention has been signed by 161 countries and has been ratified by 31 of those countries. The objective of the Convention was stated to:

> *...achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.*

The international community rallied around the threat of climate change because scientists agree that the risk is real. There is no doubt that human activities are increasing the atmospheric concentrations of greenhouse gases, especially carbon dioxide, methane, and nitrous oxide. All theoretical models predict that these increases in greenhouse gas concentrations will cause changes in climate both regionally and globally – with adverse consequences likely for human health, as well as to ecological and socioeconomic systems. The best current predictions suggest that the rate of climate change will far exceed any natural climate changes that have occurred during the last 10,000 years. Of course, there are uncertainties regarding the precise magnitude, timing and regional patterns of climate change. But any human–induced climate change that does occur will not be easily reversed for many decades or even centuries because of the long atmospheric lifetimes of the greenhouse gases and the inertia of the climate system.

Our capacity to act in the face of long–term threats is illustrated in a story about a French general who asked his gardener to plant a tree. "Oh, this tree grows slowly," the gardener said. "It won't mature for a hundred years." "Then there's no time to lose," the general answered. "Plant it this afternoon."

Global climate change is a long-term problem that will require years of sustained effort. The time for action is now.

EXECUTIVE SUMMARY

> *We must take the lead in addressing the challenge of global warming that could make our planet and its climate less hospitable and more hostile to human life. Today, I reaffirm my personal, and announce our nation's commitment to reducing our emissions of greenhouse gases to their 1990 levels by the year 2000. I am instructing my administration to produce a cost–effective plan ... that can continue the trend of reduced emissions. This must be a clarion call, not for more bureaucracy or regulation or unnecessary costs, but instead for American ingenuity and creativity, to produce the best and most energy–efficient technology.*
>
> President Clinton
> April 21, 1993

President Clinton's Climate Change Action Plan meets the twin challenges of responding to the threat

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of global warming and strengthening the economy. Returning U.S. greenhouse gas emissions to their 1990 levels by the year 2000 is an ambitious but achievable goal that can be attained while enhancing prospects for economic growth and job creations, and positioning our country to compete and win in the global market.

There is no doubt that human activity is increasing the concentration of greenhouse gases in the atmosphere. The buildup of greenhouse gases threatens to change the global climate system, raise sea levels and inundate coastal areas, inflict irreversible damage to ecosystems, and destabilize agricultural production. But the magnitude of the threat should galvanize, not paralyze, our response.

Responding to future threats with immediate action takes vision and discipline. The international community has agreed that action is necessary now, even while the impacts of climate change may take decades to fully unfold. The Framework Convention on Climate Change challenges the industrial countries of the world to begin a long journey with the proverbial first step — to return greenhouse gases to 1990 levels by the year 2000. We should strive to do no less; ultimately we will have to do more.

A full scale international response is needed to confront the climate change threat, and the United States will help to lead that effort. The President challenges the American people and other countries to meet the ambitious goals of the Framework Convention on Climate Change.

The President's Climate Change Action Plan presented here:

- **Returns U.S. greenhouse gas emissions to 1990 levels by the year 2000 with cost-effective domestic actions**;
- Includes nearly **50 new and expanded initiatives**;
- Includes measures to reduce **all significant greenhouse gases** — carbon dioxide, methane, nitrous oxide, hydrofluorocarbons and other gases;
- Takes measures in **all sectors of the economy** that emit greenhouse gases — from energy production and use to forestry initiatives;
- **Fosters partnerships** with business where focused government guidance and flexible approaches can produce cost–effective emission reductions;
- **Stimulates investments** in the technologies of the future, strengthening the American position in the global environmental technology marketplace.
- **Is backed up with real federal resources** — the Administration will commit $1.9 billion in new and redirected funding between 1994 and 2000 to the Action Plan;
- **Reduces the deficit** through two new policies. One would allow commuters the option of "cashing–out" employer–paid parking, by taking the value of the fringe benefit as taxable income. The second would permit private development at existing Federal hydroelectric facilities in exchange for lease payments. These reforms would raise $2.7 billion between 1994 and 2000;
- **Leverages over $60 billion in private investment** between 1994 and 2000 in environmental technologies. These investments pay off for U.S. businesses and citizens — the investments lead to over $60 billion in reduced energy costs between 1994 and 2000, with continued benefits of over $200 billion in energy savings between 2001 and 2010;
- **Creates new jobs** in the sectors and industries that produce, market or install technologies that save energy or reduce greenhouse gas emissions;
- Includes a **pilot program of joint implementation** to gain experience in evaluating investments in other countries for emission reduction benefits;
- **Coordinates multiple programs** to enhance their effectiveness and to strengthen their relationship with electric and gas utilities, state and local governments, and industry;
- Is designed for **rapid and aggressive implementation** and minimizes actions likely to be delayed through legislative or regulatory processes;

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- **Will be actively monitored to review progress** toward meeting the President's goal, and will institute new programs as needed to ensure that emission reductions are made; and
- **Establishes a White House team to develop strategies for long term emission reductions**, including emissions from automobiles and trucks.

OVERVIEW

America's most important assets are its people — decent, hard-working, creative and concerned. When that talent is focused through our economic and political system to solve a problem, it can accomplish great things. We have put people on the moon, we have won the cold war, and we have provided unparalleled prosperity. We can now begin to do the same for the global environment.

This plan harnesses economic forces to meet the challenges posed by the threat of global warming. It calls for limited, and focused, government action and innovative public/private partnerships. It relies on the ingenuity, creativity, and sense of responsibility of the American people.

President Clinton's Action Plan responds to the threat of global climate change and helps guide the U.S. economy toward environmentally sound economic growth into the twenty-first century. The plan is *comprehensive*, targeting all greenhouse gases and all sectors of the economy. The plan inaugurates a new era of *partnership* with American business to help solve environmental problems. The plan is designed for *rapid implementation* that can quickly deliver cost-effective results. The plan was developed by an interagency team that can quickly deliver *cost-effective* results. The plan was developed by an interagency team that relied greatly on *public input*, and is a *coordinated* federal response, involving many agencies working together. The plan will be actively monitored for effectiveness and will *adapt to changing circumstances*. Finally, the plan lays the foundation for an *international response* to this global challenge.

COMPREHENSIVENESS

Emissions of greenhouse gases are pervasive in the U.S. economy. A policy that relies on dramatic reductions of greenhouse gas emissions from one sector of the economy or one region of the country is unlikely to be effective or economic: there is no "magic bullet" that solves the problem. However, opportunities to reduce greenhouse gas emissions in cost-effective ways are distributed broadly throughout the economy. Therefore, the Climate Change Action Plan consists of almost 50 actions involving all sectors — industry, transportation, homes, office buildings, forestry and agriculture. These actions are targeted in specific sectors to stimulate markets for technologies that reduce emissions of carbon dioxide (CO_2), methane, nitrous oxide and halogenated compounds that contribute to global warming. The plan also reduces emissions of CO_2 by protecting forests, which are greenhouse gas "sinks" that store carbon removed from the atmosphere.

ESTABLISHING PARTNERSHIPS FOR PROGRESS

The Climate Change Action Plan will continue to break new ground in the relationship between government and the private sector — fostering cooperative approaches and a forward looking agenda, rather than relying exclusively on command-and-control mandates that tend to lock technologies into place and stifle innovation. These partnerships reflect the mutual responsibility of both the private sector and the government to improve environmental performance while enhancing economic growth and job creation. In several key areas — electric utilities, motor manufacturers and users, automobile manufacturers, chemical and aluminum manufacturers — American firms are entering into partnerships with the Federal government to attain environmental objectives using flexible and cost-effective options.

Today, President Clinton is announcing the **Climate Challenge**, a partnership between the Department of Energy and major electric utilities who have pledged to reduce their greenhouse gas emissions. Under the partnership, utilities have the opportunity to choose

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from a wide range of control options and to experiment with innovative ideas to achieve their emission reduction goals. The same partnership approach motivates the joint DOE/EPA **Climate Wise** program — emission targets that they can attain using the most cost–effective means available. In another initiative announced today, the DOE **Motor Challenge**, motor system manufacturers, industrial motor users, and utilities will begin an aggressive program to install the most energy–efficient motor systems in industrial applications. Chemical companies have formed a working partnership with the EPA to reduce by–product emissions of potent greenhouse gases by 50 percent from their manufacturing operations. Aluminum producers are joining the EPA to identify greenhouse gas emission reduction opportunities, and to set targets for real reductions. These new commitments — and the partnerships established between the private sector and the Federal government — provide a strong foundation for the other initiatives outlined in the Action Plan, ensuring that the programs will deliver real results.

DESIGN FOR RAPID IMPLEMENTATION
While the Action Plan contains major new initiatives, many of the actions build on the success of earlier public or private programs that have focused attention on energy savings or other emission reduction opportunities. These programs do not rely on exotic new technologies, but can help accelerate the diffusion of existing technologies into the marketplace. Much of the program outlined here can be implemented rapidly and without new legislative authority. Expanding, adapting or reinforcing innovative and successful programs will ensure that emission reductions can begin quickly enough to meet the President's goal to return greenhouse gas emissions to 1990 levels by the year 2000.

Programs that already demonstrate success on limited budgets will be expanded, largely by redirecting resources to those programs that deliver real results. Additional funding will allow successful programs to cover larger market segments or to expand into new sectors or technologies. The best programs in one agency will be adapted by other agencies and programs will be reinforced by complementary initiatives.

COST–EFFECTIVENESS
Low cost and even profitable opportunities exist to reduce emissions of greenhouse gases. While markets work well in most circumstances, significant transaction costs, information gaps, regulatory barriers and other market imperfections exist that can raise greenhouse gas emissions. Reducing these market imperfections will save money for many U.S. consumers and firms as they reduce greenhouse gases. The Action Plan targets these opportunities through public/private partnerships, allowing the private sector maximum flexibility to devise innovative programs to reduce emissions. And by taking a comprehensive approach encompassing all major greenhouse gases, both sources and sinks, and all sectors of the economy, the Action Plan offers the widest scope for creative and cost–effective actions.

PUBLIC INPUT
The President directed his Administration to tap the ingenuity and creativity of the American people. Part of that effort involved identifying innovative programs in all levels of government and in the private sector to explore their potential for reducing emissions. The White House Conference on Global Climate Change, held on June 10–11 (1993) in Washington, DC, provided the opportunity for hundreds of recognized experts in the private sector, the environmental community, academics and others to offer their suggestions and views directly to the Administration officials responsible for developing the plan and analyzing its implications. Additional workshops were held during the following months, and participants continued to offer new and innovative ideas. This plan is based on the best ideas that Americans have offered.

The Action Plan was developed in an interagency process that involved the White House and key agencies, including the Environmental Protection Agency and the Departments of Agriculture, Commerce, Energy, Interior, State, Transportation and Treasury. In addition, a team of these agencies was assigned the task of quantifying the impact of various proposals on greenhouse gas emissions and the economy.

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1.3 The President's ... Plan (con't.)

COORDINATED FEDERAL ACTIVITY
The President directed his Administration to work together for the benefit of the American people and for the environment. Too often, federal programs are a confusing and contradictory patchwork quilt that lack coordination and are poorly linked with state and local level efforts or private initiatives. This plan was developed with an unprecedented degree of cooperation at all levels in the Administration, from Cabinet Secretaries and Administrators to program managers and staff in the agencies. Implementation will require a similar degree of interagency coordination to deliver results. The National Performance Review has highlighted areas where effective coordination can deliver better performance and cost less in every area of government action. The development and implementation of this plan will apply the same lessons to the climate change problem.

ADAPTING TO CHANGING CIRCUMSTANCES
The Action Plan is expected to reach the emission reduction goal under reasonable assumptions concerning economic growth and other trends. However, a substantial degree of uncertainty accompanies any attempt to project future emission levels. The analysis supporting the plan represents a best estimate under the most likely scenario, but we recognize that these estimates could vary by a significant degree under other plausible assumptions.

The economy continually evolves in ways we cannot predict perfectly; businesses and citizens must adapt to changing circumstances. Successful policy must do the same, and this plan will evolve as circumstances warrant. A White House task force will actively monitor trends in greenhouse gas emissions and the implementation of the Action Plan, and if necessary will modify the program to keep the emission reductions on track. The first opportunity to evaluate the Action Plan is likely to come within one year. The Framework Convention on Climate Change will enter into force when 50 countries ratify the agreement, and this could occur in early 1994. Within six months of entry into force, the U.S. will submit a National Action Plan to the Conference of the Parties of the Convention. This Climate Change Action Plan, or an updated version if necessary, will form the cornerstone of the U.S. National Action Plan required by the Climate Convention. After that milestone is reached, the White House task force will reassess and update the Action Plan every two years, or sooner if called upon by the Conference of the Parties.

The Administration will also begin to identify additional opportunities for long–term emission reductions. The Action Plan focuses on near–term emission reduction opportunities in order to attain a near–term goal. Perhaps more importantly, the Plan sets in motion an ongoing press of policy development to address the long term global threat.

ENCOURAGING INTERNATIONAL EMISSION REDUCTIONS
While the plan achieves the President's goal with domestic actions alone, the Administration recognizes the significant potential for cost–effective emission reductions in other countries. The Framework Convention on Climate Change allows countries to explore emission reduction projects together under a program of "joint implementation." In order to gain experience in verifying net emission reductions from certain types of investments in other countries, the Administration is announcing the U.S. Initiative on Joint Implementation. Projects undertaken under the initiative can provide greenhouse gas emission reductions beyond the domestic programs in the President's plan and promote sustainable development. This initiative will also help advance thinking on the many issues that need resolution before an international joint implementation effort can be fully mounted. By leading the international community in developing the appropriate guidelines and criteria necessary to ensure maximum global environmental and economic benefits, the United States will help lead the international response to the climate change threat.

Introduction

1.4 Global Change Issues in National Parks: Visitor Understanding and Scientific Research

Two important social and environmental goals bring national parks and the issue of global change together. National parks effectively introduce a large number of people from various backgrounds to information about global change, and provide a research setting for global change studies in relatively undisturbed areas. The National Park Service (NPS) Mission is benefitted by both.

Global change is an issue that most likely will affect people. The understanding of global change is intimately tied to an understanding of the natural environment.

National parks are intended for the use of *all* people. Given the wide variety of clientele that parks serve, a variety of communication techniques supported by sound social science must be employed to target messages to specific groups of NPS clientele. The multifaceted nature of global change, the uncertainity about the speed and impact of climate change, per se, and physical impacts make the topic an interpretive challenge.

National parks are an ideal place for people to learn about global change issues. While exposure to global change issues will take place in the classroom, through mass media, etc., the unique opportunity that parks offer to actually *experience* the natural environment in the context of global change gives parks a clear advantage over all other means of exposure. Parks also increase the likelihood that certain sectors of the population, who would otherwise not receive exposure, are given the opportunity to learn about the issue through means that they can easily understand.

In addition to being ideal places for learning, national parks are excellent laboratories in which to study global change because of their diversity and their comparatively well-preserved ecosystems. Units of the National Park System were established to preserve their natural and cultural resources for future generations. Consequently, the system of relatively undisturbed areas across the nation is ideal for the long-term ecological research necessary to study global change and its effects. National parks contain portions of representative ecosystems in each of the major biogeographic areas of the United States. Furthermore, many parks have site-specific, long-term natural resource data sets that provide the historical framework necessary to interpret existing conditions and predict changes.

The Service's biogeographic area research approach for global change is based on the biosphere reserve model, which consists of regional centers for monitoring, research and education in characteristic ecosystems. This research program within national parks combines paleostudies, ongoing monitoring and field and laboratory research. A prominent program goal is to determine the influence of global change on life cycles of various species and the structure and functions of ecosystems in an effort to understand the extent to which natural ecosystems can adapt to environmental change.

The Service's program embraces integrated, interdisciplinary studies of park ecosystems, as well as several thematic initiatives that transcend geographic boundaries and include studies of global change impact on coastal barriers, glaciers and coral reef systems. These programs not only increase the understanding of park systems for improved resource management decisions, but also support the development and testing of regional and global change models.

It is here, in national parks, that park science and public education are linked. The topic of global change provides a framework for integrating an arrary of biological, sociological, cultural and economic topics into public education programming.

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1.5 About This Handbook

This handbook is part of the series of National Park Service (NPS) activities entitled "Interpreting Critical Resource Issues." Modeled on the Interpreting Biological Diversity Handbook published in 1991, this document is intended to provide NPS communicators and other interes ted parties with reference materials on global change issues.

The handbook is a joint effort of the Global Change Program in the Division of Wildlife and Vegetation – WASO, Interpretation Division – WASO, Chief of Interpretation Office – WRO and the School of Natural Resources, Ohio State University. A large number of interpreters, scientists and others, both within and outside NPS, provided input.

As you read this document, please keep in mind that this handbook was not designed to be a cookbook, an instruction manual or an edict. It was developed as a tool to assist a highly creative group of professionals to be even more productive in the area of global change interpretation.

This handbook is organized in the following manner:
Section 1 provides an introduction.

Section 2 contains summaries of technical materials on global change.

Section 3 consists of materials that specifically address NPS roles in interpretation and global change.

Section 4 contains content materials you may need to develop your global change communications program. Twenty fact sheets on related topics were included to provide you with an overview of the many facets of global change. Each of these fact sheets has been reviewed by a panel of university researchers, NPS scientists and interpreters, and/or outside agency delegates. For more information, or clarification, please consult those references listed at the end of each fact sheet and the bibliography. Although these fact sheets appear to cover separate topics, they are as interrelated as is our environment. Four reprints are provided as the last four fact sheets for sources of further information.

Section 5 consists of sample global change programs/materials. Each program sheet contains a general program idea designed for a variety of different audiences, interpretive techniques and park resources. All items are adaptable across media and content.

Section 6 provides a place for you to develop your park's own global change program. The article "Planning Your Global Change Program" was prepared to offer a few suggestions.

Section 7 includes a glossary, book and article bibliography and a listing of resource materials, teaching aids and audio–visual resources.

This handbook is merely a beginning. The ultimate determinant of the degree of success is the effort that individual parks and communicators make towards this undertaking. Each park, whether natural, cultural, historical or recreational — urban or rural in orientation has numerous possible global change messages. The degree to which each park chooses to participate is an individual decision based on established park themes, goals and objectives.

Please direct comments or questions to:

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Introduction

1.6 Acknowledgments

The preparation of this handbook has been a cooperative effort by NPS scientists, administrators and interpreters, and faculty and staff at Ohio State University. We gratefully acknowledge the material and technical support of all those involved.

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2.1 United Nations Framework Convention on Climate Change

The United States is a signatory to this Framework Convention. A portion of the language (Articles 1–6) of that Convention follows:

The Parties to this Convention,

Acknowledging that change in the Earth's climate and its adverse effects are a common concern of humankind,

Concerned that human activities have been substantially increasing the atmospheric concentrations of greenhouse gases, that these increases enhance the natural greenhouse effect, and that this will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind,

Noting that the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in the developing countries will grow to meet their social and development needs,

Aware of the role and importance in terrestrial and marine ecosystems of sinks and reservoirs of greenhouse gases,

Noting that there are many uncertainties in predictions of climate change, particularly with regard to the timing, magnitude and regional patterns thereof,

Acknowledging that the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions,

Recalling the pertinent provisions of the Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm on 16 June 1972,

Recalling also that States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environmental of other States or of areas beyond the limits of national jurisdiction,

Reaffirming the principle of sovereignty of States in international cooperation to address climate change,

Recognizing that States should enact effective environmental legislation, that environmental standards, management objectives and priorities should reflect the environmental and developmental context to which they apply, and that standards applied by some countries may be inappropriate and of unwarranted economic and social cost to other countries, in particular developing countries,

Recalling the provisions of General Assembly resolution 44/228 of 22 December 1989 on the United Nations Conference on Environment and Development, and resolutions 43/53 of 6 December 1988, 44/207 of 22 December 1989, 45/212 of 21 December 1990 and 46/169 of 19 December 1991 on protection of global climate for present and future generations of mankind,

Recalling also the provisions of General Assembly resolution 44/206 of 22 December 1989 on the possible adverse effects of sea level rise on islands and coastal areas, particularly low-lying coastal areas and the pertinent provisions of General Assembly resolution 44/172 of 19 December 1989 on the implementation of the Plan of Action to Combat Desertification,

Recalling further the Vienna Convention for the Protection of the Ozone Layer, 1985, and the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, as adjusted and amended on 29 June 1990,

2.1 United Nations Framework...(con't.)

Noting the Ministerial Declaration of the Second World Climate Conference adopted on 7 November 1990,

Conscious of the valuable analytical work being conducted by many States on climate change and of the important contributions of the World Meteorological Organization, the United Nations Environment Programme and other organs, organizations and bodies of the United Nations system, as well as other international and intergovernmental bodies, to the exchange of results of scientific research and the coordination of research,

Recognizing that steps required to understand and address climate change will be environmentally, socially and economically most effective if they are based on relevant scientific, technical and economic considerations and continually re-evaluated in the light of new findings in these areas,

Recognizing that various actions to address climate change can be justified economically in their own right and can also help in solving other environmental problems,

Recognizing also the need for developed countries to take immediate action in a flexible manner on the basis of clear priorities, as a first step towards comprehensive response strategies at the global, national and, where agreed, regional levels that take into account all greenhouse gases, with due consideration of their relative contributions to the enhancement of the greenhouse effect,

Recognizing further that low-lying and other small island countries, countries with low-lying coastal, arid and semi-arid areas or areas liable to floods, drought and desertification, and developing countries with fragile mountainous ecosystems are particularly vulnerable to the adverse effects of climate change,

Recognizing the special difficulties of those countries, especially developing countries, whose economies are particularly dependent on fossil fuel production, use and exportation, as a consequence of action taken on limiting greenhouse gas emissions,

Affirming that responses to climate change should be coordinated with social and economic development in an integrated manner with a view to avoiding adverse impacts on the latter, taking into full account the legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty,

Recognizing that all countries, especially developing countries, need access to resources required to achieve sustainable social and economic development and that, in order for developing countries to progress towards that goal, their energy consumption will need to grow taking into account the possibilities for achieving greater energy efficiency and for controlling greenhouse gas emissions in general, including through the application of new technologies on terms which make such an application economically and socially beneficial,

Determined to protect the climate system for present and future generations,

Have agreed as follows:

ARTICLE 1
DEFINITIONS*

For the purposes of this Convention:

1. "Adverse effects of climate change" means changes in the physical environmental or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

2. "Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

2.1 United Nations Framework...(con't.)

3. "Cli ate system" means the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.

4. "Emissions" means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

5. "Greenhouse gases" means those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation.

6. "Regional economic integration organization" means an organization constituted by sovereign States of a given region which has competence in respect of matters governed by this Convention or its protocols and has been duly authorized, in accordance with its internal procedures, to sign, ratify, accept, approve or accede to the instruments concerned.

7. "Reservoir" means a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored.

8. "Sink" means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.

9. "Source" means any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere.

ARTICLE 2
OBJECTIVE

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

ARTICLE 3
PRINCIPLES

In their actions to achieve the objective of the convention and to implement its provisions, the Parties shall be guided, inter alia, by the following:

1. The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.

2. The specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change, and of those Parties, especially developing country Parties, that would have to bear a disproportionate or abnormal burden under the Convention, should be given full consideration.

3. The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.

2.1 United Nations Framework...(con't.)

4. The Parties have a right to, and should, promote sustainable development. Policies and measures to protect the climate system against human-induced change should be appropriate for the specific conditions of each Party and should be integrated with national development programmes, taking into account that economic development is essential for adopting measures to address climate change.

5. The Parties should cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country Parties, thus enabling them better to address the problems of climate change. Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade.

ARTICLE 4
COMMITMENTS

1. All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall:

(a) Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties;

(b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change;

(c) Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors;

(d) Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems;

(e) Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods;

(f) Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change;

(g) Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies;

(h) Promote and cooperate in the full, open and prompt exchange of relevant scientific,

2.1 United Nations Framework...(con't.)

technological, technical, socio-economic and legal information related to the climate system and climate change, and to the economic and social consequences of various response strategies;

(i) Promote and cooperate in education, training and public awareness related to climate change and encourage the widest participation in this process, including that of non-governmental organizations; and

(j) Communicate to the Conference of the Parties information related to implementation, in accordance with Article 12.

2. The developed country Parties and other Parties included in annex i commit themselves specifically as provided for in the following:

(a) Each of these Parties shall adopt national[1] policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. These policies and measures will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objective of the Convention, recognizing that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol would contribute to such modification, and taking into account the differences in these Parties' starting points and approaches, economic structures and resource bases, the need to maintain strong and sustainable economic growth, available technologies and other individual circumstances, as well as the need for equitable and appropriate contributions by each of these Parties to the global effort regarding that objective. These Parties may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention and, in particular, that of this subparagraph;

(b) In order to promote progress to this end, each of these Parties shall communicate, within six months of the entry into force of the Convention for it and periodically thereafter, and in accordance with Article 12, detailed information on its policies and measures referred to in subparagraph (a) above, as well as on its resulting projected anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol for the period referred to in subparagraph (a), with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol. This information will be reviewed by the Conference of the Parties, at its first session and periodically thereafter, in accordance with Article 7;

(c) Calculations of emissions by sources and removals by sinks of greenhouse gases for the purposes of subparagraph (b) above should take into account the best available scientific knowledge, including of the effective capacity of sinks and the respective contributions of such gases to climate change. The Conference of the Parties shall consider and agree on methodologies for these calculations at this first session and review them regularly thereafter;

(d) The Conference of the Parties shall, at its first session, review the adequacy of subparagraphs (a) and (b) above. Such review shall be carried out in the light of the best available scientific information and assessment on climate change and its impacts, as well as relevant technical, social and economic information. Based on this review, the Conference of the Parties shall take appropriate action, which may include the adoption of amendments to the commitments in subparagraphs (a) and (b) above. The Conference of the Parties, at its first session, shall also take decisions regarding criteria for joint

[1]This includes policies and measures adopted by regional economic integration organizations.

2.1 United Nations Framework...(con't.)

implementation as indicated in subparagraph (a) above. A second review of subparagraphs (a) and (b) shall take place not later than 31 December 1998, and thereafter at regular intervals determined by the Conference of the Parties, until the objective of the Convention is met;

(e) Each of these Parties shall:

(i) coordinate as appropriate with other such Parties, relevant economic and administrative instruments developed to achieve the objective of the Convention; and

(ii) identify and periodically review its own policies and practices which encourage activities that lead to greater levels of anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol than would otherwise occur;

(f) The Conference of the Parties shall review, not later than 31 December 1998, available information with a view to taking decisions regarding such amendments to the lists in annexes i and ii as may be appropriate with the approval of the Party concerned;

(g) Any Party not included in annex i may, in its instrument of ratification, acceptance, approval or accession, or at any time thereafter, notify the Depositary that it intends to be bound by subparagraphs (a) and (b) above. The Depositary shall inform the other signatories and Parties of any such notification.

3. The developed country Parties and other developed Parties included in annex ii shall provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations under Article 12, paragraph 1. They shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed between a developing country Party and the international entity or entities referred to in Article 22, in accordance with that Article. The implementation of these commitments shall take into account the need for adequacy and predictability in the flow of funds and the importance of appropriate burden sharing among the developed country Parties.

4. The developed country Parties and other developed Parties included in annex ii shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects.

5. The developed country Parties and other developed Parties included in annex ii shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies.

6. In the implementation of their commitments under paragraph 2 above, a certain degree of flexibility shall be allowed by the Conference of the Parties to the Parties included in annex i undergoing the process of transition to a market economy, in order to enhance the ability of these Parties to address climate change, including with regard to the historical level of anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol chosen as a reference.

7. The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account that economic and social

2.1 United Nations Framework...(con't.)

development and poverty eradication are the first and overriding priorities of the developing country Parties.

8. In the implementation of the commitments in this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on:

(a) Small island countries;

(b) Countries with low-lying coastal areas;

(c) Countries with arid and semi-arid areas, forested areas and areas liable to forest decay;

(d) Countries with areas prone to natural disasters;

(e) Countries with areas liable to drought and desertification;

(f) Countries with areas of high urban atmospheric pollution;

(g) Countries with areas with fragile ecosystems, including mountainous ecosystems;

(h) Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products; and

(i) Land-locked and transit countries. Further, the Conference of the Parties may take actions, as appropriate, with respect to this paragraph.

9. The Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology.

10. The Parties shall, in accordance with Article 10, take into consideration in the implementation of the commitments of the Convention the situation of Parties, particularly developing country Parties, with economies that are vulnerable to the adverse effects of the implementation of measures to respond to climate change. This applies notably to Parties with economies that are highly dependent on income generated from the production, processing and export, and/or consumption of fossil fuels and associated energy-intensive products and/or the use of fossil fuels for which such Parties have serious difficulties in switching to alternatives.

ARTICLE 5
RESEARCH AND SYSTEMATIC OBSERVATION

In carrying out their commitments under Article 4, paragraph 1 (g), the Parties shall:

(a) Support and further develop, as appropriate, international and intergovernmental programmes and networks or organizations aimed at defining, conducting, assessing and financing research, data collection and systematic observation, taking into account the need to minimize duplication of effort;

(b) Support international and intergovernmental efforts to strengthen systematic observation and national scientific and technical research capacities and capabilities, particularly in developing countries, and to promote access to, and the exchange of, data and analyses thereof obtained from areas beyond national jurisdiction; and

(c) Take into account the particular concerns and needs of developing countries and cooperate in improving their endogenous capacities and capabilities to participate in the efforts referred to in subparagraphs (a) and (b) above.

2.1 United Nations Framework...(con't.)

ARTICLE 6
EDUCATION, TRAINING AND PUBLIC AWARENESS

In carrying out their commitments under Article 4, paragraph 1 (i), the Parties shall:

(a) Promote and facilitate at the national and, as appropriate, subregional and regional levels, and in accordance with national laws and regulations, and within their respective capacities:

(i) the development and implementation of educational and public awareness programmes on climate change and its effects;

(ii) public access to information on climate change and its effects;

(iii) public participation in addressing climate change and its effects and developing adequate responses; and

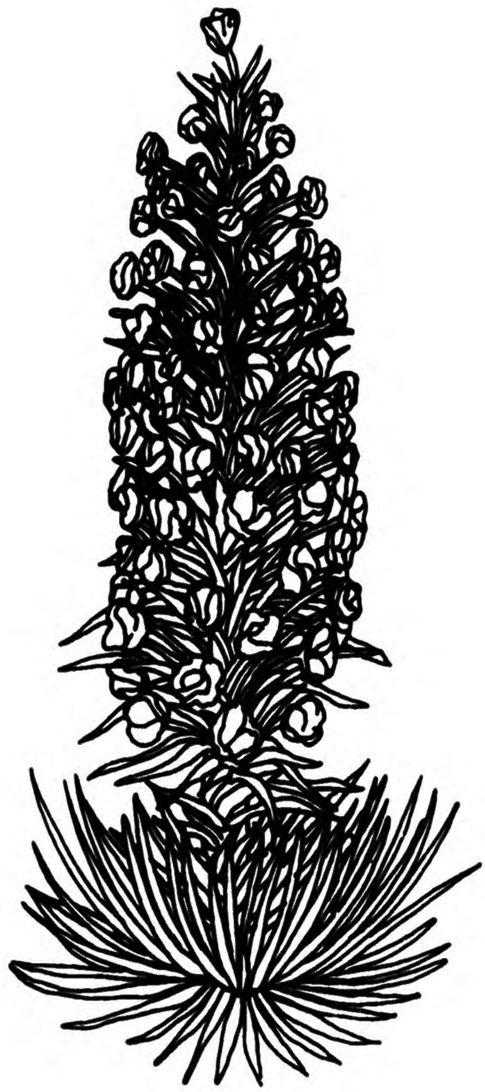
(iv) training of scientific, technical and managerial personnel.

(b) Cooperate in and promote, at the international level, and, where appropriate, using existing bodies:

(i) the development and exchange of educational and public awareness material on climate change and its effects; and

(ii) the development and implementation of education and training programs, including the strengthening of national institutions and the exchange or secondment of personnel to train experts in this field, in particular for developing countries.

The full Convention text also includes Article 7–26 (mostly focused towards membership procedures) and two appendices listing countries involved.



2.2 A Summary of "Global Change Information Packet"*

**A 1992 second edition packet was produced by the National Agricultural Library, U.S. Department of Agriculture. The following material is excerpted from the packet insert, which lists the materials included in the information packet.*

The National Agricultural Library (NAL) has prepared this "Global Change Information Packet" on global climate change to provide information for the public. Included are concerns surrounding and potential effects of global climate change, lists of books and journal articles that discuss these concerns fully, and a description of how to obtain additional information.

NAL is part of the U.S. Department of Agriculture, the largest agricultural library in the world, containing 2.1 million volumes and receiving more than 26,000 current periodical titles from around the world. Along with the Library of Congress and the National Library of Medicine, NAL is one of the three national libraries of the United States.

Contents of the 1992 "Packet" include:

Global Climate Change and Agriculture — A Summary; Susan C. Whitmore.
Chronology of Global Climate Change; Jayne T. MacLean.
Global Climate Change Selected Annotated Bibliography; Douglas E. Jones.
Directory of Global Climate Change Organizations; Janet Wright.
Global Climate Change Pathfinder: A Guide to Information Sources; Chestalene Pintozzi and Douglas E. Jones.
Global Warming and the Greenhouse Effect (Quick Bibliography 92–36); Jayne T. MacLean.

Selected global climate change articles included in the "Packet" are:

Ausubel, Jesse H. 1991. "A Second Look at the Impacts of Climate Change." *American Scientist* pp. 210–221.
Brookes, Warren T. 1989. "The Global Warming Panic." *Forbes* pp. 96–102.
Houghton, Richard A. and George M. Woodwell. 1989. "Global Climate Change." *Scientific American* pp. 36–44.
Kellogg, William W. 1991. "Overview of Global Environmental Change: The Science and Social Science Issues." *Marine Technology Society (MTS) Journal* pp. 5–11.
Rind, David. 1989. "A Character Sketch of Greenhouse." *EPA Journal* pp. 4–7.

For copies of this free "Global Information Packet" send your request and a mailing label to:

National Agricultural Library
Reference Section, Room 111
National Agricultural Library
10301 Baltimore Blvd.
Beltsville, MD 20705

Editors: Janet Wright and Douglas E. Jones.

Report Summaries

2.3 A Summary of *Policy Implications of Greenhouse Warming**

**This report was prepared by the Synthesis Panel of the Committee on Science, Engineering and Public Policy of the National Academy of Sciences, National Academy of Engineering and Institute of Medicine. It was published in 1991 by and is available from the National Academy Press (Washington, DC). The following materials are excerpted or paraphrased from the panel report.*

The HUD–Independent Agencies Appropriations Act of 1988 (House Report 100-701:26) called for:

> *....a National Academy of Science study on global climate change. This study should establish the scientific consensus on the rate and magnitude of climate change, estimate the projected impacts, and evaluate policy options for mitigating and responding to such changes. The need for and utility of improved temperature monitoring capabilities should also be examined, as resources permit.*

According to subsequent advice received from members of the U.S. Congress, the study was to focus on relatively active trace gases from human sources or "greenhouse warming." This report, summarized herein, is one of the products of that study.

The report presents background information about greenhouse warming and its relationship to human activities, as well as a thorough overview of greenhouse gases and their effects, before considering the policy implications of greenhouse warming.

In considering possible responses to greenhouse warming, several issues must first be considered:

- The extent, timing and variation of future warming and its likely impacts need to be assessed.
- Both the cost and the effectiveness of options to slow greenhouse warming must be estimated and compared to the costs of postponing action.
- The possible advantages and disadvantages of these actions need to be evaluated in light of the extent to which people, plants and animals are likely to adjust by themselves or with outside assistance to changes in the climate.
- The policy–maker needs to evaluate these actions in comparison to other ways resources might be used.
- Decision–makers will judge all these factors in a broader context. Responses to greenhouse warming will be determined by people worried about economic growth, food supply, energy availability, national security and a host of other problems.

The conclusion that "despite uncertainties, greenhouse warming is a potential threat sufficient to justify action now" is followed by recommended responses. Recommendations aim to reduce the speed and magnitude of greenhouse warming and to prepare people and natural systems of plants and animals for future adjustment to the conditions likely to accompany greenhouse warming.

The following recommendations are enumerated to offset or reduce current emissions:

- Continue the aggressive phaseout of chlorofluorocarbons and other halocarbon emissions and focus on the development of substitutes that minimize or eliminate greenhouse gas emissions.
- Study in detail the "full social cost pricing" of energy, with a goal of gradually introducing such a system.
- Reduce the emission of greenhouse gases during energy use and consumption by enhancing conservation and efficiency.
- Make greenhouse warming a key factor in planning for our future energy supply mix. The United States should adopt a systems approach that considers the interactions among supply, conversion, end use and external effects in improving the economics and performance of the overall energy system.
- Reduce global deforestation.

Report Summaries

2.3 A Summary of Policy...(con't.)

- Explore a moderate domestic reforestation program and support international reforestation efforts.

The following recommendations are enumerated in the report to help make affected systems less vulnerable to future climate change:

- Maintain basic, applied and experimental agricultural research to help farmers and commerce adapt to climate change and thus ensure an ample food supply.
- Make water supply more robust by coping with present variability by increasing efficiency of use through water markets and by better management of present systems of supply.
- Plan margins of safety for long-lived structures to take into consideration possible climate change.
- Move to slow present losses in biodiversity.

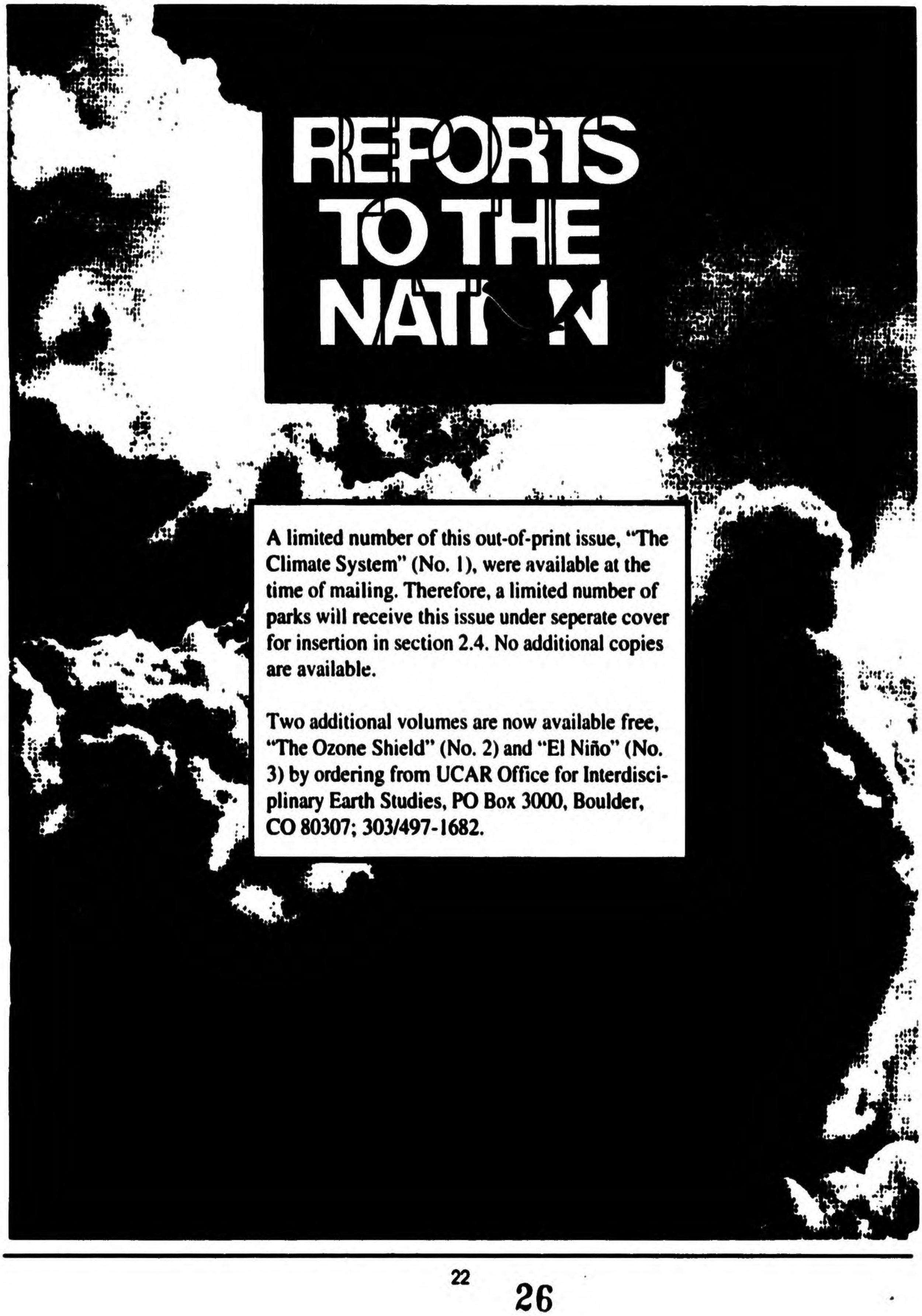
The following recommendations to improve knowledge for future decisions, evaluate geoengineering options and exercise international leadership are also set forth:

- Continue and expand the collection and dissemination of data that provide an uninterrupted record of the evolving climate and data that are (or will become) needed for the improvement and testing of climate models.
- Improve weather forecasts, especially of extremes, for weeks and seasons to ease adaptation to climate change.
- Continue to identify those mechanisms that play a significant role in the climatic response to changing concentrations of greenhouse gases. Develop and/or improve quantification of all such mechanisms at a scale appropriate for climate models.
- Conduct field research on entire systems of species over many years to learn how carbon dioxide enrichment alters the mix of species and changes the total productions or quality of biomass. Research should be accelerated to determine how greenhouse warming might affect biodiversity.
- Strengthen research on social and economic aspects of global changes and greenhouse warming.
- Undertake research and development projects to improve our understanding of both the potential of geoengineering options to offset global warming and their possible side effects. This is not a recommendation that geoengineering options should be undertaken at this time, but rather that we learn more about their likely advantages and disadvantages.
- Control of population growth has the potential to make a major contribution to raising living standards and to easing environmental problems like greenhouse warming. The United States should resume full participation in international programs to slow population growth and should contribute its share to their financial and other support.
- The United States should participate fully with officials at an appropriate level in international agreements and in programs to address greenhouse warming, including diplomatic conventions and research and development efforts.

The Synthesis Panel reached the collective judgment that the United States should undertake not only several actions that satisfy multiple goals but also several whose costs are justified mainly by countering or adapting to greenhouse warming.

Report Summaries

2.4 "Reports to the Nation on Our Changing Planet"



A limited number of this out-of-print issue, "The Climate System" (No. 1), were available at the time of mailing. Therefore, a limited number of parks will receive this issue under seperate cover for insertion in section 2.4. No additional copies are available.

Two additional volumes are now available free, "The Ozone Shield" (No. 2) and "El Niño" (No. 3) by ordering from UCAR Office for Interdisciplinary Earth Studies, PO Box 3000, Boulder, CO 80307; 303/497-1682.

Report Summaries

2.5 U.S. Office of Technology Assessment Report

Changing by Degrees: Steps to Reduce Greenhouse Gases (1991), produced by the Office of Technology Assessment (OTA), Congress of the United States, is a report to the Congress and the nation on the issue referred to as "global warming." This 370-page report is also available as a 56-page summary. The following is a summation of that report. All data are attributable to that source.

"The United States is the world's leading industrial society and largest single emitter of carbon dioxide. Climate change therefore presents a unique challenge to this nation. It is a threat that will require major prudent political actions even before all the scientific uncertainties are resolved" (pg. *iii*). The assessment focuses on ways to cut carbon dioxide (CO_2) emissions — the primary contributor to projected global warming — both in the U.S. and worldwide.

The assessment stresses major reductions in CO_2 and other greenhouse gases will require significant new initiatives by the federal government, by the private sector and by individual citizens. Some initiatives will pay for themselves; others will have considerable economic costs.

Efforts must be worldwide because a 50 to 80 percent CO_2 reduction from present daily levels, according to the U.S. Environmental Protection Agency, is required just to maintain present day levels. Burning of fossil fuels and economic pressures, coupled with population increases, are the major factors in global warming. The potential warming can be addressed if societies are willing to mandate more energy — efficient technologies as a means of buying time as we shift to nonfossil fuel energy sources.

Changing by Degrees does not examine in depth many equally difficult questions such as the science of climate change, the uncertainties and state of atmospheric modeling or the projected ecological effects of global warming. Rather, most of OTA's resources have been devoted to analyzing technical options to decrease CO_2, although methane, nitrous oxide and chlorofluorocarbon (CFC) emissions are addressed wherever possible. At the time of their request, the congressional committees were well aware of ongoing international efforts to phase out CFCs and halons; since OTA's study began, successful negotiations have been completed. OTA's report sought to answer the following question: "Can the United States reduce carbon dioxide emission in the near-term?" (pg. 4).

To answer the question Congress posed, OTA focuses specifically on potential emissions reductions in the next 25 years. The analysis is structured around six key sectors of the U.S. economy: buildings, transportation, manufacturing, energy supply, forestry and food. To the extent possible, the report quantifies the potential for emissions reduction within each sector — areas where gains in efficiency, product substitution, conversion or other technical options can ameliorate increases in CO_2 and other greenhouse gases. A selection of policy options that appears to offer the most promise for achieving these reductions in the United States is presented. OTA was charged to look abroad as well, so the special needs of eastern Europe, the U.S.S.R. and developing countries — with respect to both energy and natural resource issues — are also addressed.

In the detailed analysis of potential emissions reductions for the United States, consideration was given an extensive suite of technical options. For example, estimates were made for the potential increments of CO_2 reduction from electric utility fuel switching, possible improvements in automobile efficiency, changes in commercial building construction, more efficient manufacturing processes, etc. Most of the options relate to decreasing emissions, although some, such as reforestation, involve recapturing gases already emitted to the atmosphere.

The assessment lays out three paths: a base case ("business as usual"), a moderate (essentially "no-cost") case and a tough case. Only the last fulfills the congressional request and reduces future CO_2 emissions — to a level in 2015 that is 20 to 35 percent lower than today. According to the report some will argue that estimates of emissions reductions are both politically unattainable and

2.5 U.S. Office of Technology...(con't.)

costly. Others will decry a 20 to 35 percent reduction as not nearly enough. The Intergovernmental Panel on Climate Change and the U.S. Environmental Protection Agency recently estimated that the world must reduce CO_2 emissions by at least 50 to 80 percent to stabilize the atmosphere. Congress' request for work within a 25-year time frame in the study proved to be a two-edged analytic sword. It forced OTA to take a close look at where U.S. CO_2 emissions were heading without policy intervention. But, 25 years also is too short a period to include a scenario in which fossil fuels are supplanted with such nonfossil fuel sources as renewable and improved nuclear energy sources.

Indeed, the United States as described 25 years hence in this report does not sound fundamentally different from what we know today. However, an underlying theme in OTA's report is that a strong research and development (R&D) effort is pivotal to bringing non-CO_2 (i.e., nonfossil fuel) sources to commercialization as quickly as possible, even as all sectors of the economy move to use more efficient equipment and decrease energy consumption. If long-term R&D is geared to that purpose, then new nonfossil supply technologies can start to replace existing powerplants and equipment early in the next century.

Many of the technical options evaluated in the report are worth pursuing for other reasons, in addition to climate change, because they address other important U.S. goals such as energy security, local environmental quality and economic competitiveness. They can reduce emissions in the short-term, reduce total energy demand and serve to bridge the U.S. economy from a fossil fuel age to a nonfossil future.

For information on how to request copies of *Changing by Degrees: Steps to Reduce Greenhouse Gases* or the *Summary*, contact:

Superientendent of Documents
Government Printing Office
Washington, DC 20402-9325

2.6 Joint Climate Change Project Report

Purpose
The Joint Climate Project To Address Decision-makers' Uncertainties (1992) identified the major questions U.S. decision-makers have about global climate change and then had scientists determine what research and time frames would be required to address these questions. This project helped fill a critical need for more explicit communication between decision-makers and scientists on the information requirements for policy development and the capabilities of research to meet those requirements.

Sponsors
The Joint Climate Project was a federal/private sector effort sponsored by the following:

Electric Power Research Institute
  Environment Division
U.S. Environmental Protection Agency
  Office of Research and Development
U.S. Department of the Interior
  Offices of the Secretary and Program Analysis
U.S. Department of Energy
  Offices of Energy Research and Fossil Energy
U.S. Department of Agriculture
  Global Change Program Office
U.S. Forest Service
  Forest Fire and Atmospheric Sciences Research
National Oceanic and Atmospheric Administration
  National Climate Program Office

Science and Policy Associates, Inc. (SPA) designed and conducted the project with a steering committee composed of representatives from the sponsoring organizations.

Approach
The first phase of this unique project included dozens of U.S. government and private sector officials, ranging from working level experts to congressional representatives, Administration officials and industry CEOs convened to define their key questions about global climate change. The iterative process lasted six months and included a series of interviews, workshops and focus groups that resulted in a consensus set of broad, policy-relevant questions for researchers to address. Examples of groups represented in defining the decision-makers' questions include:

> U.S. Departments of Agriculture, Energy, the Interior and State; Environmental Protection Agency; Office of Management and Budget; Office of Technology Assessment; Council of Economic Advisors; Council on Environmental Quality; National Governors' Association; U.S. Congress; chemical, coal, oil, natural gas and electric utilities; manufacturing, transportation, forest products industries and environmental groups.

During the second phase of the project, leading experts in climate-related disciplines were assembled to discuss the decision-makers' questions developed during the preceding months. The workshop participants examined (i) the research needed to address the questions and (ii) the expectations for providing better information over the next two, five, ten years and beyond. In addition, the project examined the needs and opportunities for improving the dialogue between decision-makers and researchers.

Findings
The consensus-identifying approach of this project yielded several key findings that reflect the general concerns of decision-makers and the responses of the research community. In discussions with these two communities, several common themes also emerged for enhancing communication and increasing the value of research results.

The Concerns of Decision-makers

- *International Perspectives Drive Policy*: Many government policy-makers are focusing primarily on ongoing international negotiations and conferences, such as the United Nations Conference on Environment and Development (UNCED) and the Framework Convention on Climate Change. Information is needed to support preparations for such events and for

2.6 Joint Climate Change...(con't.)

follow-up actions. Non-government decision makers are concerned with the possible regulatory implications of proposed actions.

- *Climate Change Impacts and Responses Key to Decision Making*: Decision making is driven by concerns about the potential impacts of changing climate at the regional level, rather than predictions of changing global mean values of climate variables. More information is needed from the economic, social and ecological sciences on the potential regional impacts of climate change and the consequences of possible response strategies.

- *Interim Information Needed*: Researchers need to provide interim information and iterative assessments while developing long-term answers. These interim reports should be as explicit as possible about the inherent uncertainties and avoid compromising scientific objectivity. This need for interim information is driven by the decisions made during relatively short time periods, depending on cycles in politics, budgets and public concern.

- *Implications of Uncertainties Need Clarification*: Researchers need to clarify the sources and implications of policy-relevant scientific uncertainties, and estimate time frames to reduce them. There is a need to define better which uncertainties are most important for policy development and resource management, and the practical implications of these uncertainties for decision makers.

- *Certainty Not a Prerequisite for Action:* Resolution of all scientific uncertainties is not a prerequisite for policy action. Decision makers will apply their constituents' values to determine how much certainty they judge is enough to take a given policy action.

Details of the priority questions of decision-makers regarding the climate system, potential impacts of climate change and responses are discussed in the section on Phase 1 in the full report (pp. 27–34).

The Response Of Researchers

- *Timely Results*: Some of the key questions decision–makers have about climate change can be addressed within a short time frame on the basis of the analysis and interpretation of already available scientific information. Although more complete scientific understanding of climate change may be decades away, much of the information needed to begin addressing decision–makers' questions can be provided within two to five years. This could include a comprehensive evaluation of indicators of global climate change, a preliminary vulnerability analysis for systems and regions most sensitive to climate change and an assessment of the sources and levels of greenhouse gas emissions for use in identifying potential mitigation and adaptation options.

- *Parallel Approach to Climate, Impacts and Responses Research*: Scientists need not wait for accurate climate prediction before beginning their research on potential impacts and response options. It is neither necessary nor practical for research to progress sequentially from the climate system, to the impacts and then to the potential responses in order to provide useful results for decision-makers.

- *Greater Emphasis Needed on Impacts and Responses Research*: Information on climate change impacts and response strategies has the greatest potential to help decision-makers, yet these fields are the least researched. Many of the key questions identified by decision-makers involve a significant amount of new socioeconomic, behavioral and ecological research.

- *Funding Alone is Not Enough*: The pace of intellectual and technological advances will affect the progress of research independent of funding levels. Increased communication and coordination among research areas and disciplines, hard sciences, economics and behavioral sciences are critical to answering decision-makers' questions.

- *Useful Information before Reliable Predictions*: Much can be done to improve the understanding of impacts without waiting for accurate regional

2.6 Joint Climate Change...(con't.)

climate predictions. Integrated regional and multi–sectoral models, using climate, ecological, demographic, economic and social data collected at the regional level can provide essential information on potential climate responses even before more precise climate predictions are available. For example, research could determine the vulnerability of key systems and bound the extreme ranges of change.

- *Integrated Assessments and Case Studies*: Integrated assessments of the causal linkages from emissions through impacts and responses would help structure information for effective use in decision making. Such assessments would incorporate natural and physical sciences, economics and social factors, including technological change and adaptation. In addition, a coordinated examination of case studies of regional climate variability is needed, based on how societies have responded to climatic variations, using historically documented events. This information would provide valuable insights on how to treat future events.

Tables 1, 2 and 3 provide a brief summary of the potential types of information that research could offer to address decision-makers' concerns in two, five and ten years. These time frames were chosen by the decision-makers because of key periods in international negotiations and other activities such as the following:

— **1993** (coinciding with follow-up actions to the U.N. Conference on Environment and Development)

— **1996** (coinciding with the Third World Climate Conference)

— **2000–2005** (coinciding with dates proposed by some in the international community for initial targets and timetables for greenhouse gas emissions stabilization/reduction)

—**2025–2030** (coinciding with dates referred to by some scientists for a potential doubling of greenhouse gas concentrations)

The following tables provide an educated estimate by scientists of the potentially available information for time frames of interest to decision-makers. They were developed without regard to financial or other resource constraints. These lists suggest what research could do, and not what currently planned efforts will do. For more details, refer to the specific research areas discussed in Phase 2 of the full report (pp. 35–81).

Table 1 Examples of Potential Research Results Within One to Two Years

Understanding Climate Change
- Comprehensive evaluation of climate change indicators with attributed cause
- Synthesis of existing data to identify significant trends
- Case studies of past climate changes

Impacts of Climate Change
- Preliminary vulnerability assessment of systems and regions most sensitive to climate change
- Simulation models that include ecological, meteorological, demographic and economic factors
- Preliminary development of environmental change scenarios for regional assessments
- Syntheses of impacts data for use in integrated climate change assessments
- Case studies of impacts of past climate changes

Responding to Climate Change
- Assessment of land use patterns and the sources and levels of greenhouse gas emissions
- Inventory of actions that imply relatively long-term commitments to emissions at particular levels
- Incorporation and analysis of existing environmental laws and regulations into current economic models, and analysis of their economic and environmental impacts

2.6 Joint Climate Change...(con't.)

- Information on potential mitigation and adaptation options
- Catalogue of existing programs addressing climate change
- Methods to evaluate effectiveness/consequences of various policy instruments for implementing mitigation and adaptation strategies
- Economic analyses to evaluate the costs and benefits of response options
- Preliminary assessment of adaptation potential
- Information on interrelationships between U.S. and international activities
- Review of reconstructive ecology
- Case studies of human responses to past climate changes

Table 2 Examples of Potential Research Results Within Five Years

Understanding Climate Change
- Higher spacial resolution GCMs
- Improved understanding of cloud–radiation feedback
- Improved understanding of atmosphere–ocean interaction
- Evaluation of impacts of other climate forcing mechanisms (e.g., ozone and sulfate aerosols)
- General geographic distribution of climate changes

Impacts of Climate Change
- Information on basic processes influencing changes in systems
- Preliminary baseline monitoring of present state of ecosystems
- Better understanding of how to incorporate technological change and adaptation into impacts analyses
- Regional-scale, future-oriented research on regional vulnerabilities
- Procedures to evaluate validity of existing and future models
- Evaluation of resource conflicts
- Assessment of factors affecting environmental carrying capacity in various situations
- Integrated system studies for various systems and sectors
- Progress towards integrated, interdisciplinary research and assessment
- Continued synthesis of paleoecological information
- Impact assessments for developing countries
- Examination of effects of international trade and aid on food and other resources

Responding to Climate Change
- Refinement of economic analyses to evaluate costs and benefits of response options
- Initial catalogue of species and sites for use in adaptation analyses
- Preliminary assessment of techniques to aid species migration
- Assessment of technical and institutional responses to major resource shortages

Table 3 Examples of Potential Research Results Within Ten Years

Understanding Climate Change
- Well-defined climate change scenarios to evaluate regional effects
- Improved understanding of magnitudes and rates of change
- More information on atmosphere-ocean-ice interactions and climate feedbacks
- Better understanding of climate responses to changing concentrations of greenhouse gases and other mechanisms of climate change
- Ongoing improvements in evaluating predictions of geographic patterns; the role of land-surface processes to predict local and regional climate change near the ground; and the influence of climate change on the biosphere
- Improved weather forecasts

Impacts of Climate Change
- More defined baseline information on the present state of ecosystems
- Development of a global change social science research program
- Materially closed ecosystem studies to determine effects of climate changes

2.6 Joint Climate Change...(con't.)

- Better understanding of species and system response to CO_2 enrichment
- Better understanding of potential climate change impacts
- Further refinement of assessments

Responding to Climate Change

- Better understanding of social and economic aspects of global change and greenhouse warming
- Information on social behavior and social structures
- Further refinement of assessments

Lessons in Communication

- *Not an Either/Or Decision*: Decision-makers' choices are not simply either to pursue research or to implement response strategies. Rather, the challenge is to define the appropriate levels of each over time. Researchers need to provide a broad array of information to address the complex and interacting decisions on global climate change. Decision-makers, for their part, need to recognize the long-time scales involved in research and, thus, the importance of continuity of funding and program goals.

- *Global Climate Change in a Relative Risk Context*: Prediction of changes in mean global temperatures does not give an adequate picture of the societal risk that can be related to everyday experiences. Assessing climate change in a relative risk context is difficult, but extremely important. Since the public tends to respond to perceived crises, assigning relative risk would assist decision-makers distinguishing between verifiable serious threats and possibly misplaced public concern. Given that risk is a function of both the probability and the magnitude of the expected consequences, better data on possible impacts are critical to better estimates of societal risk.

- *Urgent Need for Education:* A concerted effort is needed to educate decision-makers on the facts and uncertainties of global climate change. Considering that public concern is often the impetus for formulating policy, scientists need to communicate technical information to the public more effectively, as well as more frequently. In addition, scientists need to learn more about the decision making process and the types of information most useful for policy. Frequent, two-way communication between decision-makers and researchers is fundamental if research is to play an effective role in the decision making process.

- *Managing Uncertainty:* There are more ways to manage uncertainties than simply trying to reduce them. For example, building resilient institutions and methodologies would provide a flexible response to any future changes in climate, albeit at potentially significant costs. Contingency plans could allow decision–makers to prepare for possible climate outcomes through R&D on response technologies, without needing to deploy them. Furthermore, decision-makers and researchers should strive to understand and communicate more effectively the risks of climate change.

- *Research Does Not Always Provide the Answer:* Decision–makers need to realize that additional research actually could increase the amount of uncertainty in some areas. Researchers should inquire about how much certainty decision-makers require to take a specific action. To this end, uncertainties that do not matter for decision making should be so identified.

- *Develop an Ongoing Assessment Process for Research:* To improve communication and better inform decision-makers, research efforts should include an iterative assessment process. These assessments would not only help to identify the relevant questions, but also serve to structure the research results and, thus, facilitate clearer communication between the two communities. Furthermore, the assessment process would provide valuable input to the planning of policy-relevant research.

2.6 Joint Climate Change...(con't.)

Next Steps

The *Joint Climate Project to Address Decision-makers' Uncertainties* represents an important step in determining what research can do to assist U.S. decision-makers over the coming years and decades. An ongoing process of systematic communication between the decision making and the research communities is essential. Efforts such as this help ensure that the nation reaps the maximum practical benefits from the growing investments in climate-related research and development.

The results of this project will be widely communicated through high-level briefings to government agencies and private sector groups. The final report also will be distributed to the decision making and research communities, as well as to the media. The sponsors of the Joint Climate Project have agreed to reconvene the Steering Committee after the United Nations Conference on Environment and Development (UNCED). This will be an opportunity to plan for updating the decision-makers' questions and responses of researchers developed during this initial project, in light of science and policy developments.

The initial insights and general information from this pioneering project should be extended to the local, regional and international levels. Furthermore, the preliminary findings presented here should be periodically evaluated and updated as research progresses and policy evolves. The process started in this project can serve as a foundation and model for the necessary continued efforts to bridge the gap between science and policy.

PROJECT REPORT QUALIFIER:
The views reported herein express the consensus opinions of the individual project participants, and do not necessarily represent the views of the sponsors or their institutions. An exhaustive and statistically representative survey of all relevant groups and viewpoints was beyond the scope of this effort. Furthermore, the report neither attempts to define the current state of science nor provides a critique of specific research programs or policy options.

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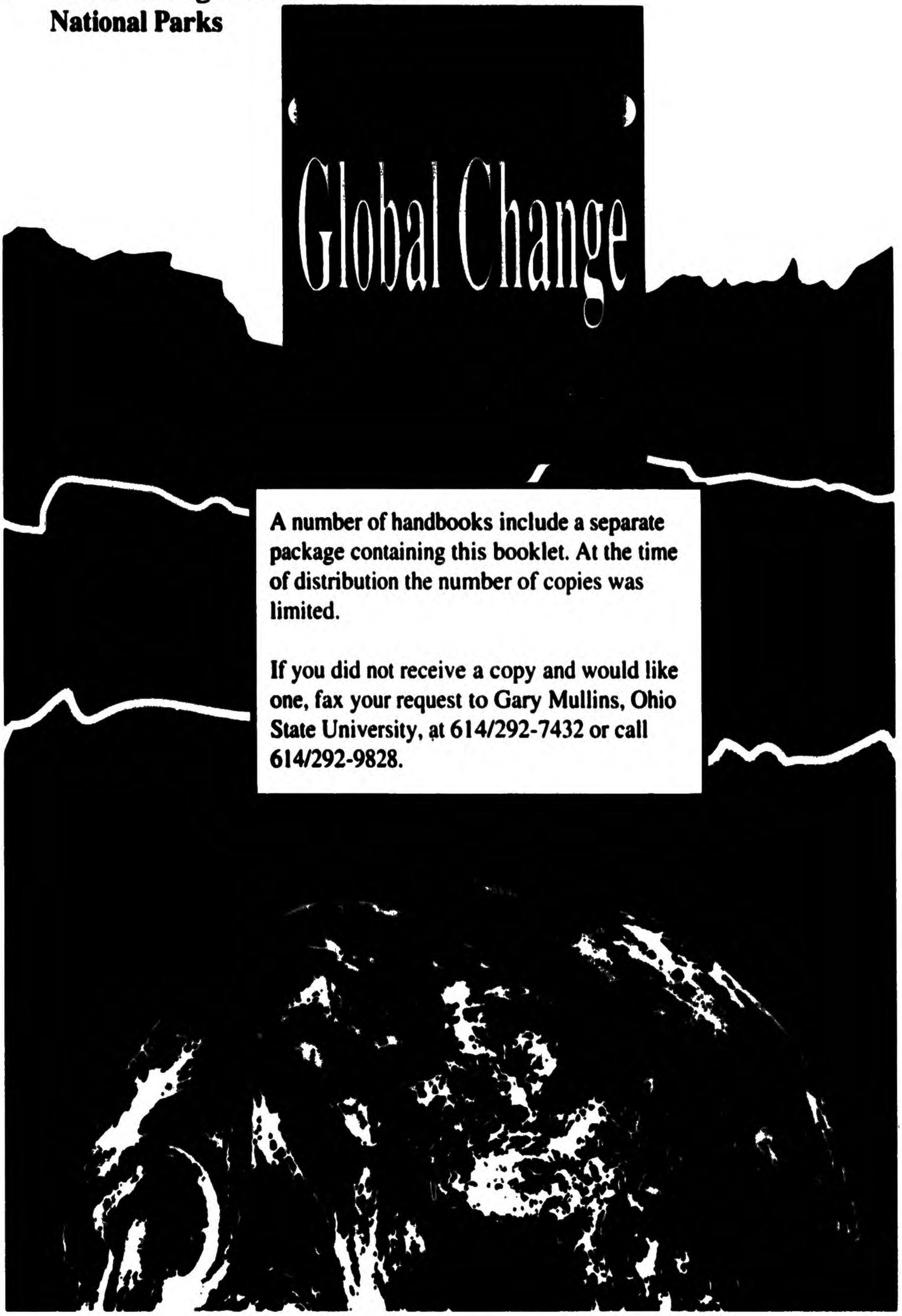
Background Papers

3.1 Global Change Research in U.S. National Parks



A number of handbooks include a separate package containing this booklet. At the time of distribution the number of copies was limited.

If you did not receive a copy and would like one, fax your request to Gary Mullins, Ohio State University, at 614/292-7432 or call 614/292-9828.

3.2 Role of U.S. National Parks in Global Change Research

ABSTRACT
The U. S. National Park System encompasses a rich suite of potential locations for global change research, including a wide range of environmental gradients. We have selected 20 biogeographical areas for developing a long-term global change research program. The program relies on designated and potential biosphere reserves as principal research sites. It is designed to enlist the expertise of the academic community, other federal agencies, resident park scientists and resource managers, and to facilitate interdisciplinary cooperation on scales from local to international.

We are organizing our program according to internationally recognized biogeographical provinces. We are implementing park-based studies in particular biogeographical areas that will contribute to predictive understanding of global change effects on the province. We are working to share research data internally and externally, and to develop appropriate data management protocols. We initiated research in 1991. Our initial experience underscores the benefits and practical difficulties of integrating park-based research in a cooperative international research program.

Introduction

During the hot, dry summer of 1988, the greater Yellowstone area burned with an intensity probably not seen for 150 years or more. In a few weeks, an ecosystem was transformed. In 1989, Hurricane Hugo, with peak winds in excess of 330 km/hr, plowed the reefs and forests of the Virgin Islands and Puerto Rico, then reworked the shoreline and flattened the evergreen forests of the South Carolina coast. The effects of these disturbances will be studied for decades as the ecosystems establish a new dynamic. We cannot say whether global warming was a factor, but we do know that these are the kinds of phenomena to be expected more frequently under global change (GC).

In the next century, natural ecosystems may begin to experience unprecedented changes in the magnitude, seasonality, frequency, geographic extent and duration of climatic extremes. The effects of changes in wildfire, drought, severe storms, unusual precipitation patterns and extremes of heat and cold would be interactive and cumulative with the effects of CO_2 fertilization, sea level rise, enhanced ultraviolet radiation (related to stratospheric ozone depletion) and other factors in global change.

Species would be differentially affected according to their sensitivity to the particular combinations of stresses. Under such conditions, ecological communities that took millennia to develop could dissociate rapidly. To address this situation, aggressive management on a scale unimaginable today would be required to enable the continuing evolution of many species in the wild. Whether such management of natural ecosystems will even be possible is highly problematic (National Academy of Sciences, 1991). However, managers must begin to address the consequences of global change predictions that currently exist (Joyce, Fosberg and Comanor, 1990).

In recent decades, we have learned much about the practice of ecosystem management. We routinely prescribe burns to restore the natural role of fire in fire-dependent ecosystems, like the Everglades and Sequoia National Parks. We are successfully restoring wetlands and endangered species, especially mammals and vascular plants, and using integrated management approaches to control exotic species. The goal of U.S. national parks and many natural areas is to restore natural processes disrupted by human influences, either directly or indirectly. The implicit assumption is that once we repair the damage, we can reduce or eliminate the need for active management to sustain natural processes and species populations.

Rapid directional changes in atmospheric composition and global climate would have profound implications for national park managers. Protected areas would become unsuitable for many species they now support, and newly suitable for species now found elsewhere. For many species, migration across

3.2 U.S. National Parks...(con't.)

natural barriers or landscapes fragmented by human uses would be especially problematical. For some, migration to or from protected area habitats would be impossible without management assistance. Under such conditions, cooperative management of large biogeographical areas (BGA) offers the best chance for maximizing biodiversity and minimizing the biological impoverishment of the protected areas (Parsons, 1991).

Cooperative management of BGAs is a desirable management goal. However, it is difficult to achieve in practice. Managing agencies and organizations often have vastly different policies and public constituencies. Consensus on management goals is often difficult to achieve. In this environment, cooperation in developing and sharing scientific information now can pave the way for stakeholders to work together later on the more difficult task of responding to complex regional management issues. Unfortunately, most BGAs do not yet have a cooperative framework for pooling intellectual, technical and financial resources to develop and share information.

A BGA may be defined as a geographic area within a terrestrial biogeographical province (Udvardy, 1975) or coastal region (Ray, 1975) that is distinguishable on the basis of some combination of physiography, climate, vegetation, characteristic species, natural processes, human populations and characteristic resource uses. It is essentially a biogeocultural region (U.S. MAB, 1989) containing one or more protected areas that provides an optimal scale for managing most components of biological diversity, and for practical actions to address many human influences on ecosystem processes. The scale is suitable for integrating the natural and social sciences in understanding the complex factors in ecosystem sustainability, and for demonstrating participatory democratic approaches in using scientific information effectively for solving ecosystem management problems.

The Promising Role of Biosphere Reserves

The scientific and educational value of the world's outstanding conservation areas may ultimately be their finest legacy to human society. Biosphere reserves (BR) uniquely enable these areas to contribute relevant scientific information for sustaining ecosystems at scales ranging from local to global (Dyer and Holland, 1991). A BR offers the potential of linking park-based research with other research in the BGA, the larger biogeographical province, other biogeographical provinces within the same biome and among the biomes comprising the global Earth system. These linkages strengthen the role of protected areas to society as bellwethers of ecosystem change and benchmarks for assessing the effects of human activities. By expanding the constituency for this role, BRs encourage commitment to long-term research programs.

BRs help their stakeholders achieve a balance among ecosystem uses in a way that sustains the natural ecosystem processes and the biological resources of their BGA. Many countries have organized multi-sector associations of government, non-governmental entities and local people around the unifying BR concept. Flexibly adapted to the conditions of the BGA, the new organizations provide needed permanent forums for stakeholders in ecosystem sustainability to discuss the resource issues that concern them on a regular basis and learn the art of cooperation. They are building the broad public constituency for the research, education and demonstration projects that make solutions possible. Ultimately, these cooperative organizations may prove to be the BRs' greatest contribution. As these emerging organizations succeed in pooling intellectual, technical and financial resources locally, opportunities for linkages with issues and activities at wider scales will inevitably emerge. Some BRs are already contributing useful data to improve general circulation models and predictions of the regional effects of global change. However, their practical management benefits will come in the future as BRs use the models to formulate and demonstrate adaptive strategies for sustaining ecosystems and biological diversity under conditions of global change.

3.2 U.S. National Parks...(con't.)

The National Park Service's Global Change Program: A Biogeographic Area Approach
The NPS Global Change Program (NPSGCP) seeks to provide predictive and holistic understanding of the effects of global change on species populations, ecological communities, watershed processes and landscape dynamics through the coordinated use of parks as benchmark research sites within larger BGAs. In each BGA, cooperation with other agencies and organizations involved in global change research is an important program goal. To optimize the possibilities for networking inherent in the biosphere reserve model, each BGA includes at least one existing or potential NPS unit of the International Network of Biosphere Reserves. This core research area is the focus of most of the NPS research. However, in some BGAs, one or more contributing NPS units are also involved. These support the BGA program by providing complementary resources, research capabilities and data sets. They also make possible the opportunity to complete the research design, corroborate results, test research hypotheses and apply predictive modeling to the BGA and the larger biogeographic province.

The NPSGCP also includes thematic initiatives that complement the BGA programs. These primarily involve coastal and marine systems. They are multi-regional, and focus on specific research topics. An initiative to understand potential global change effects on coastal barrier dynamics is underway, and another on the structure and physiology of coral reefs is planned.

Each BGA has a designated research coordinator and funding for operational support of a long-term research program. Most coordinators are located at regional universities, which provide access to interdisciplinary research capabilities. To date, we have initiated global change research in six temperate forest BGAs: the Olympic Peninsula, the Central and Southern Sierras, the Glacier National Park Area, the Colorado Rockies, the Ozark Highlands and the Western Great Lakes. During the next year, we expect to add BGAs in the Central Grasslands, South Florida (Everglades), Sonoran Desert and the Gulf Coast. At full development, the program is planned to include 20 BGAs, representing most of the biomes in the United States. Research will be initiated as funding and cooperative research opportunities develop.

Ongoing research varies among the BGAs, reflecting (among other things) the historical research strengths of the participating parks, the park and university expertise, the sensitivity of the resources to global change and the results of a rigorous peer-review and competitive selection process. Ongoing projects support four of the seven science elements in the interagency U.S. Global Change Research Program (Committee on Earth and Environmental Sciences, 1991): Earth System History, Ecological Systems and Dynamics, Biogeochemical Dynamics and Climate and Hydrologic Systems. The initial projects emphasize particular areas of disciplinary study. However, the overall objective is to link these studies with future NPS and outside research at many scales to develop interdisciplinary assessments and, eventually, adaptive response strategies for the larger areas.

Opportunities for global change networking, such as found in the Great Smoky Mountains National Park (GRSM), are plentiful. The park has a long history of site level monitoring and research relevant to global change. It participates in the Southern Appalachian Man and the Biosphere (SAMAB) Cooperative, an organization of eight federal and state agencies for cooperation on regional resource issues. The Cooperative's activities focus largely on the Southern Appalachian Biosphere Reserve, which includes GRSM, two long-term ecological research areas, three additional areas nominated for inclusion and a large surrounding "area of cooperation." A nonprofit SAMAB Foundation facilitates private-sector participation. The park is also part of a large BGA, which is being considered for inclusion in the NPSGCP. The BGA includes Shenandoah National Park, a satellite research site recently selected as the prototype for biological inventory and monitoring to help address many issues, including global change. At wider spacial scales, the U.S. Global Change Research Program (USGCRP) facilitates regional and national research linkages. International biome-based linkages for global change research will benefit from

3.2 U.S. National Parks...(con't.)

efforts of European and North American Man and the Biosphere Programs to strengthen cooperation among their biosphere reserves, and the international activities of the Intergovernmental Panel on Climate Change (IPCC, 1990, 1991) and the Scientific Committee on Problems of the Environment (SCOPE, 1990).

A Preliminary Program Assessment
Integrating national parks into the complexities and many scales of global change research will take time. However, the NPSGCP has taken important steps that have broad implications for strengthening the role and credibility of research in national parks and the role of parks in addressing issues of ecosystem sustainability. We provide a brief assessment of the program's strengths and weaknesses at this early implementation stage in order to assist others contemplating a similar research effort.

Program development relied on an open competition of proposals based on a conceptual research plan for the BGA. The process tapped the creativity and experience of agency and outside researchers. It resulted in the selection of parks in western mountain areas with a strong history of research. On the other hand, plans and proposals reflected the limited familiarity and experience of park researchers with global change issues. Many were not well focused on the research issues and priorities of the USGCRP. The initial selections were not biogeographically balanced.

This program has the most extensive outside peer review of any program NPS has undertaken. The review, which occurs at both concept plan and proposal stages, has helped establish credibility both inside and outside the agency. Yet this critical evaluation resulted in rejection of many proposals that were desirable to achieve an integrated, interdisciplinary program but did not meet the scientific review criteria.

This is the first linkage of U.S. national parks to a highly structured domestic and international research program to address a global issue. Although the program was designed to contribute significantly to this effort, a modest funding level has delayed the initiation of research in many BGAs.

A committee of NPS scientists and managers, selected on the basis of professional expertise, coordinates the national program. This is the agency's first use of such a mechanism, which has been particularly successful.

This is the first NPS nationally-directed research program to have a full-time data administrator. This underscores commitment to contribute well documented, quality data sets to the national effort.

The program has created a field organization to facilitate research on a BGA rather than administrative area basis. While the approach has enhanced possibilities for ecologically-based cooperation, coordinators supported under the national program have sometimes had difficulty managing activities across administrative areas having different capabilities, interests and local priorities.

We are the only federal land managing agency to adopt the cooperative BGA approach for GC research. However, cooperation has been easier to conceptualize than to implement because agency development of on-site research has necessarily taken priority over inter-site linkages in the initial program implementation stage.

Conclusions
The NPSGCP's success has been reflected in the quality of the research proposals, the enthusiastic support of field units and the intense competition for the field coordinator positions. However, achieving the larger goal of an integrated, multi-agency, cooperative BGA research effort would benefit from having BR research linkages with other agencies and organizations in place prior to preparing GC research plans. These associations could help coordinate research objectives among agencies in the BGA and link them to USGCRP milestones. Proposals could be considered in 'sets' rather than individually, brought up to standards and integrated before the

3.2 U.S. National Parks...(con't.)

BGA is funded and the research commenced. If necessary, the type of research desired in each BGA could be cooperatively specified at the start, and proposals solicited by the participating entities accordingly.

Our initial experience indicates the utility of organizing GC research on a BGA basis, with emphasis on use of the BRs. These areas may provide the most suitable framework for communication among the many sectors with a stake in achieving ecosystem sustainability in ways that maintain biological diversity under changing environmental conditions.

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3.3 Paleoecological Studies of Global Change

Paleoecological records can contribute essential information for understanding global change in ecosystems. Preserved in fossil records of pollen, plant macrofossils, diatoms, foraminifera, animal bones and sediment chemistry are the past responses of ecosystems to changes in climate, hydrology, soil development and competition. Understanding the linkages among these global systems and their responses to past climatic change is critical for the design of sound ecosystem models. Ecosystem modeling can predict future conditions only if the model has incorporated the essential elements of natural systems.

Fossil records allow an understanding of the relationships between these essential elements by demonstrating the different habitats that have resulted from conditions different from those of today. For example, a theoretical reconstruction of the vegetation that existed during the mid-Holocene period, roughly 6,000 years ago, can demonstrate the result of a greater amount of summer sunlight during this period caused by the shifting of the Earth's orbit around the sun. During this period, annual average temperatures were two degrees Celsius (3.6 degrees Fahrenheit) warmer in some parts of the northern hemisphere, roughly the average temperature predicted by some models by the year 2040 A.D. This period cannot serve as an exact analog for future expected greenhouse conditions primarily due to differences in the rate of change, but it is as close an analog as can be found. Reconstruction of past environments during this period will provide an approximation of the future potential limits to species, provided they can migrate fast enough through the remaining patches of habitat by that time.

By running an ecosystem model using the different boundary conditions that prevailed in the past (such as summer insolation), paleoecological records provide an independent verification of computerized ecological models. If a model is sound enough to simulate the past, it has a greater likelihood of correctly simulating the future.

Paleoecological studies can also aid the understanding of natural ecological dynamics by providing examples of past responses to changes. For example, a reconstruction of the past vegetation of an area (through fossil pollen) can be coupled with a reconstructed fire history (from fossil charcoal or fire scars on trees), allowing an understanding of the relationship between fire and vegetation. Because natural fire regimes will most likely be changing in the future, and fire can be actively manipulated, this understanding will be essential for the future management of national parks.

Paleoecological records also increase our understanding of changing ecosystems by documenting the magnitude of past and ongoing vegetational changes. Are ecosystems undergoing rapid change today? This question can only be answered by comparing ongoing rates of change with those that have prevailed in the past. All ecosystems are in a perpetual state of change, some changing quickly enough to be noticeable, while others change so slowly that no change is evident within the span of our monitoring record.

Paleoecological studies can quantify the amount of past change and estimate the rate of current ongoing change by extending the monitoring baseline back hundreds of years. Knowledge of current environmental trends allows extrapolation into the future in order to predict future environmental states, even if no greenhouse warming takes place. Without this extended baseline, there is no way to distinguish between the results of ongoing change and change brought about by warming climates.

Contributed by Kenneth L. Cole, NBS Global Change Research Coordinator, Western Great Lakes BGA.

Background Papers

3.4 Research in National Parks

Reprinted from *The Northwest Environmental Journal* Vol. 7, No. 2, Fall/Winter 1991.

The Response of Tree Growth to Global Climate Change: Subalpine Forest of the North Cascade Mountains

David W. Peterson and David L. Peterson, National Biological Survey, Cooperative Park Studies Unit, College of Forest Resources (AT-10), University of Washington, Seattle, Washington 98195

The subalpine zone is an ideal place to look for a response to climate change, because it is an area where climatic conditions (especially temperature and snowpack) are limiting to tree growth. This study is examining the past and present growth of four common subalpine tree species to climate. Subalpine larch (*Larix lyallii*), whitebark pine (*Pinus albicaulis*), subalpine fir (*Abies lasiocarpa*), and Englemann spruce (*Picea engelmannii*) all grow near treeline in the North Cascade Mountains of Washington State. The annual growth rings of mature subalpine tree species contain a biological time sequence of growth responses to environmental stress of up to 500 years. Climatic conditions predicted for this area as a result of global climate change have been experienced over short time periods in the past, and the growth response to these conditions is recorded in tree rings. The primary objective of this study is to identify the climatic conditions that most strongly affect the growth of subalpine trees. The time series of tree growth will give us a basis for predicting growth responses to potential climatic changes in the future.

A second objective of the study is to compare the growth response of the same four subalpine tree species growing under similar environmental conditions in the North Cascades. Paleoecological studies have shown that species respond individually to past climatic changes, resulting in changes in species assemblages over time (Brubaker, 1988). It should be possible to determine how future forest composition might change through examination of past responses of different species to various climatic conditions (drought, warm summers, wet winters, etc.).

Two study sites have been established in the subalpine zone (approximately 2,000 m elevation) of the east-central North Cascades. Trees were sampled on three landforms that affected species composition and tree density at each site: ridge top, main slope, and valley bottom. Cores have been collected from 20 trees of each species that occurs on each landform at each site. Growth responses to climate are being examined using dendrochronology (tree ring analysis) (Fritts, 1976).

Our research will identify the environmental factors that most strongly determine the annual variation in growth of subalpine forest species on different landforms in the North Cascades. It will help predict growth responses in subalpine forests under potential future climate change, and indicate if growth response could lead to a long-term change in the composition of these forests.

References

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3.4 Research...(con't.)

Effects of Climate on Regeneration of Subalpine Forests after Wildfire

Ronda L. Little and David L. Peterson, National Biological Survey, Cooperative Park Studies Unit, College of Forest Resources (AR-10), University of Washington, Seattle, Washington 98195.

Several physiological and mechanical stresses, such as soil frost, intense radiation, desiccation, wind, snow cover, and fire, influence the survival of high elevation tree species (Tranquillini, 1979). Future changes in climate could affect the magnitude of these stresses. Even small changes in environmental stress can induce responses in high elevation forests of the Pacific Northwest, especially in young forests. Older trees are resilient to many environmental changes that are lethal to young conifers; therefore, climatic fluctuations during early forest development can act to select the ultimate species composition of mature forests.

Major disturbances, such as fire, provide the opportunity to study interactions between climate and seedling establishment (regeneration) by removing existing trees and exposing newly established seedlings to the present climatic regime. Disturbances may actually increase the rate of forest response to climate change through altered species frequency or composition (Agee and Smith, 1984). Current associations of forest species in the Pacific Northwest have formed only recently (3,000 to 5,000 years ago), and each species responds independently to climatic variation, creating different forest communities (co-occurring groups of populations) than in the past (Brubaker, 1988).

This study addresses the following questions: What climatic conditions influence regeneration of subalpine conifers after wildfires? Two high elevation (1,700 m) wildfires that burned at the turn of the century and have naturally regenerating forests are being examined just northeast of Mount Rainier in Washington State. Conifer species found in these burned areas include subalpine fir (*Abies lasiocarpa*), noble fir (*A. procera*), Pacific silver fir (*A. amabilis*), mountain hemlock (*Tsuga mertensiana*), Engelmann spruce (*Picea engelmannii*), Alaska yellow cedar (*Chamaecyparis nootkatensis*), whitebark pine (*Pinus albicaulis*), lodgepole pine (*P. contorta*), western white pine (*P. monticola*), ponderosa pine (*P. ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*). Regeneration at the study sites is being studied by determining the age of conifers that germinated following the fire. We will determine the effect of climate in the years surrounding germination and on seedling survival in subsequent years. Different species may become established under different climatic and microsite (that is, small-scale features such as logs or soil depressions) conditions, and regeneration patterns may vary with topography and location. Information on the effects of climate and other factors on conifer establishment can be used by forest resource managers to predict the regeneration rate and species composition of subalpine forests after fire.

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3.4 Research...(con't.)

Sensitivity of Subalpine Forests in the Pacific Northwest to Global Climate Change

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It has been suggested that the effects of potential climate change on forests of the Pacific Northwest will be minimal due to its generally moderate climate. This line of thinking fails to recognize that forest distribution and productivity in this region are limited by climatic extremes expressed over short geographic distances and steep elevation gradients. Low-elevation forests are sensitive to moisture deficits during relatively dry summers, and high-elevation species are sensitive to winter snowpack that shortens the length of the growing season. Subalpine forests (Zobel et al., 1976) and meadow ecosystems are an important, climatically sensitive component of the regional vegetation of the Pacific Northwest. Changes in temperature, precipitation, snowpack, storm frequency and fire could affect the growth and productivity of these systems, resulting in substantial shifts in the location of transition areas (ecotones) between subalpine/alpine zones and maintain/subalpine zones (Canaday and Fonda, 1974). Subalpine areas in the Olympic and Cascade Mountains provide an excellent opportunity to examine responses to past climate variability. Trees in subalpine forests of the Pacific Northwest reach up to 500 years of age, and respond to climatic variations over annual to century-long time scales, including extreme events. The magnitude of this variation may be comparable to that projected for the future as a result of global climate change. The population (groups of individuals within a species) dynamics of subalpine tree species can be used to interpret climatic conditions under which trees have regenerated, and can indicate how subalpine forest/meadow ecotones may have changed during the last century. Preserved pollen and plant fossils can be used to examine subalpine communities 10,000–6,000 yr before present, when warmer, drier summers existed in the Pacific Northwest.

The National Park Service has initiated a long-term research program on global climate change in the Pacific Northwest that focuses on potential effects in the subalpine zone of National Parks and adjacent public lands. The program emphasizes studies at the population and community (co-occurring groups of populations) levels or organization, because effects of climate change will be detected earlier there than at more complex levels or organization. The major goals of this research are to: (1) reconstruct forest community composition during the current interglacial period; (2) determine the relationship of tree growth to climate, especially extreme events; (3) investigate regeneration of forest species after disturbances such as fire; and (4) observe recent changes in subalpine/alpine community distribution and their relationship to climate. The results of this research program will allow us to predict changes that could occur under future climate scenarios. These predictions can be used to develop a management strategy that can anticipate and, perhaps, mitigate future changes in the condition of natural resources.

References

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Background Papers

3.4 Research...(con't.)

Climatic Effects on Establishment of Subalpine Fir (*Abies lasiocarpa*) in Meadows of the Olympic Mountains

Andrea Woodward, Michael B. Gracz and Edward G. Schreiner, Natural Science Studies, Olympic National Park, 600 East Park Avenue, Port Angeles, Washington 98362.

Establishment of trees in subalpine meadows in the Cascade Mountains has been shown to be periodic and in response to climatic variation (Franklin et al., 1971; Heikkinen, 1984). Specifically, establishment has occurred during periods of high temperatures and low precipitation, which result in early snowmelt and longer growing seasons. These conditions existed in the Olympic Mountains during 1930–1945 and more intensely during 1977–1981, although it is not known if there are age classes of subalpine tree species that correspond to these time intervals. The press of establishment is important to the future composition of subalpine areas because it determines the potential for tree species distribution to change in response to potential global climate change.

Subalpine fir (*Abies lasiocarpa*), a major treeline species in the Olympic Mountains, can establish only in areas having specific soils, moisture conditions and snow-free periods (Lowery, 1972). Drought causes longer snow-free periods and facilitates establishment in areas where length of growing season is limiting. Establishment cannot occur in locations that are too dry, have very late snowmelt, or have unsuitable soils. Various plant communities (co-occurring groups of populations), which reflect current growing conditions, have different levels of suitability for tree establishment. These communities may serve as indicators of the potential for subalpine fir to become established in new areas under various precipitation regimes.

We are studying the recent establishment of subalpine fir in meadows of the Olympic Mountains to understand the relationship among climate and establishment, and potential subalpine fir habitat. We are determining tree age and site characteristics at six sites, two each in wet (southwest), moderate (central), and dry (northeast) regions. Site growing conditions are indicated by plant community, slope, aspect, and soil. We will compare meadow types with year of establishment and climate for different drought severities (with emphasis on the 1930–1945 and 1977–1981 periods discussed above). This will enable us to determine the potential habitat and distribution of subalpine fir under various climate change scenarios.

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3.4 Research...(con't.)

Tree Establishment in Subalpine Meadows of Mount Rainier National Park

Regina M. Rochefort and David L. Peterson, National Biological Survey, Cooperative Park Studies Unit, College of Forest Resources (AR-10), University of Washington, Seattle, Washington 98195.

Subalpine parklands are a transition between continuous subalpine forest and the treeline/alpine border. The subalpine parkland zone of Mount Rainier National Park is characterized by a mosaic of tree clumps and open subalpine meadows between approximately 1,600 and 2,200 m elevation. Although factors that determine the extent and location of these meadows are not well understood, there is evidence that meadow boundaries respond to climate change. Periodic tree establishment in meadows has been documented in the late 1800s and 1930s during periods of reduced snowpack and warmer temperatures (Franklin et al., 1971; Henderson, 1974). More recent periods of seedling establishment in meadows have been documented in Alberta, Canada during periods of above average temperatures in the late 1960s (Kearney, 1982).

We are studying the current status of subalpine fir (*Abies lasiocarps*) and mountain hemlock (*Tsuga mertensiana*) seedling establishment (regeneration) in subalpine meadows of Mount Rainier National Park by resampling previously established permanent plots in subalpine parklands. Tree size and age data indicate that there have been periods of conifer establishment since those documented in the 1930s. We are analyzing patterns of this recent period of regeneration to determine how they might be related to climate or other environmental factors.

The subalpine meadows of Mount Rainier National Park are well known for their spectacular floral displays, and approximately 60 percent of the two million people who visit the park annually go to view wildflowers in the meadows (Salvi and Johnson, 1985). Several of the park's subalpine meadows are managed specifically for their historic value as flower fields, and concern about increasing tree densities led to a tree removal program in the 1970s. Increased understanding of the factors affecting seedling establishment of subalpine tree species will improve predictions of the future composition of the subalpine parkland zone. This will provide better information on which to base management alternatives in response to potential climate change and increased resource demands.

References

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Background Papers

3.5 Global Change: An Interpretive Opportunity

There are certain parks within the National Park System that are well-known for the opportunity to observe specific wildlife species. Everglades National Park is noted for seeing alligators, wood storks and roseate spoonbills. Big Bend National Park is the only place within the United States to see the Colima warbler. Channel Islands National Park is home to six species of pinnipeds. To see sooty terns, brown and black noddy terns and masked bobbies one needs to visit Dry Tortugas National Park. Yellowstone National Park is justly famous for its large mammal species, including moose, elk, deer and grizzly bear. To see some of America's most endangered birds and plants requires a visit to Haleakala National Park. Global change could dramatically alter some of these biological "givens" in the future.

The national parks of the United States are great repositories of biological diversity. They will become even more so in the future as development and urbanization increase externally to park boundaries. The parks are also important scientific "laboratories" in which the effects of global change can be monitored and future changes in disturbance and biota can be predicted. The parks provide opportunities in paleoecological research on insights to past climatic disturbances and how natural communities responded to those changes. Where appropriate, biotic changes might be predicted by modeling forest and aquatic ecosystem succession and by modeling changes in habitat and their associated species composition.

The impacts of global climate change on the national parks (and of course, upon our everyday lives) will be extremely significant. It has been postulated that a two degree Fahrenheit increase in average annual temperature in the United States would cause Michigan's hardwood forests to begin to be replaced by grasslands, Eastern U.S. forests would move northward into Canada, affecting parks such as Great Smoky Mountains, Shenandoah, Blue Ridge Parkway and Cumberland Gap. Western forests would shrink in size, either being exterminated or compacted as they move upslope on mountains. Rising sea levels would inundate America's coastal areas, flooding coastal parks, monuments and urban areas, destroying coastal wetlands and permeating freshwater supplies. Everglades and Biscayne National Parks, and all of our national seashore parks and coastal military fortification parks, will be adversely affected.

Other serious impacts ascribed to global change processes include changes in amounts and patterns of distribution in precipitation, evaporation and wind resulting in the frequency and severity of storms, such as hurricanes and wildfires. Significant changes will take place in our daily lives as climatic alterations will shift or disrupt current agricultural zones. Coinciding with Earth's increasing human population, there will be greater demand for food and forest products along with living and recreational space. All of these potential changes will affect the national parks. They will certainly affect visitor use of the parks. How global climate change will alter or even replace existing park biological systems and visitor use systems are two of the great challenges facing National Park Service managers in the 21st century.

What should be the role of National Park Service interpreters regarding global change? Since we are not professional climatologists or experts in the field of ecological change, how should we deal with this highly complex and controversial subject? The purpose of this handbook is to help answer those questions.

In the overall processes of global change, the role of interpretation is related directly to what the role of the national parks will be. Because of their biological richness and their geographical locations, the national parks will be inventoried, monitored and studied for indications of global changes for decades to come. The parks will be "yardsticks" by which change will be measured.

But who will explain these changes in the parks? The scientists? The resources management specialists? In the best of their historical tradition, National Park Service interpreters will have one of the greatest

Background Papers

3.5 An Interpretive Opportunity...(con't.)

opportunities of any federal agency employee to communicate global change. We can do this through our traditional interpretive programs and media — and we can do it right on site where the changes may occur (or are occurring) and can be experienced by the public.

Though the results of global change as a phenomenon will most likely affect every unit in the National Park System, global change will not necessarily be appropriate to every park's interpretive program. Historical and cultural parks will not be exempt from global change consequences and could choose to justifiably interpret them. When the wheat growing zone has shifted out of the United States northward into Canada, will the historical relevance of the wheat field at Gettysburg become an anachronism? Will interpreting 12–14th century A.D. southwestern Native American dwellings, abandoned centuries ago due to changing climate, have greater meaning and personal significance to 21st century visitors who themselves are experiencing the ramifications of changing climates? Will climate change create new growing conditions for different crops at national park sites where agriculture is an interpretive demonstration?

Interpreting global change should become a fundamental educational opportunity for the National Park Service. Global change has the potential to affect many of the natural, cultural, aesthetic and economic aspects of our daily lives. As human life and culture will change, so too will the national parks and the ways they are used. The ecosystems of 21st century national parks may well be very different from the way we know them today and vastly different from the way they looked when they were established.

Therein lies our educational challenge and our interpretive message.

Contributed by Richard L. Cunningham, Chief of Interpretation, NPS Western Region.

Background Papers

3.6 Communicating Critical Resource Issues

"Don't Worry — Be Happy" just doesn't cut it when it comes to acid deposition, desertification, loss of biological diversity or global change. As the voices for the ailing environment, we must go beyond traditional interpretation and address environmental realities.

William Penn Mott, at the 1986 Conference on Science in the National Parks, stated, "It is not enough for us to gather knowledge. It is not even enough for us to apply that knowledge. It is essential that we share our knowledge with the people of the nation and this world."

Incorporating critical resource issues interpretation into your program schedule involves seven major stages: identifying the problem, educating yourself, understanding global relationships, building your own park specific resource base, planning the program, interpreting and evaluating.

Identifying the Problem
Critical natural resource issues spring forth from findings made by scientists and resource managers (Whatley and Sikoryak, 1988). When topics such as global change with all of its uncertainties and varying levels of predictions are introduced, the interpretation of this critical resource issue becomes most complex. Potential global change-related problems do not exist in isolation, however. Each problem is linked to other major problems such as acidic deposition and loss of biological diversity. Finding the links between issues makes interpretation more holistic.

Education
A most critical stage of interpreting critical resource issues begins with your own basic science education. You, and later the audience, need to have knowledge of the basic scientific principles and ecological relationships around which the critical issues revolve. A superficial understanding of these principles is not adequate — in order to relate to the audience we must understand. Discoveries and advancements in scientific issues such as global change are astounding. While popular books and textbooks may provide general background information on the topic, most factual results will be out of date before you read them. This handbook provides you with some general background information. However, you are encouraged to refer to other publications as listed in the references section for further clarification and details. Your NPS and NBS scientists should be utilized. You may also wish to use members of your local scientific community as sources for information.

Understand Global Relationships
Interpreting critical resource issues such as global change provides us with "opportunities to explore the universal concepts of the diversity of life in the parks' unique stories and to relate how each park's resources are connected with national and global resources" (according to Carol Spears, NPS Chief of Interpretation, Channel Islands National Park). To effectively interpret your park's global change story, you must understand the relationships between that story and what is happening globally, as well as locally. This is where you will establish importance or significance in the visitors' minds.

Building Your Own Park Specific Resource Base
Once you have your issue clearly identified and have built your own personal knowledge base, start the search for resources to help you interpret the issue to the public. Gather all the scientific studies conducted in your park or in a similar park in your biogeographical region and build a set of park specific fact and program sheets. Programs developed at other parks are also an excellent source of ideas.

Planning Programs
Planning your critical resource issue program goes beyond the use of regular program principles outlined by Tilden, Sharpe, Ham and various other interpretive texts. Your goal goes beyond entertainment to high impact education. That is not to say that interpreting critical resource issues cannot be enjoyable, but just enjoyment is not your focus. Target your message to those who it suits most. Consider planning programs with heavy content and high involvement for those visitors who already have a thorough understanding of your park environment. Many of these individuals will already be aware of the issue and some of its ramifications. Your

3.6 Communicating...(con't.)

programs cannot therefore be simplistic. For the uninitiated, try weaving your issue into more general themes or simply use one or two examples of issue-related material in existing programs. As the awareness level of these individuals increases, they will be more willing to accept specialized programming on the topic. No matter who your audience is, the concepts you need to present are difficult and may be controversial. To assure understanding, develop a tangible recurring message element or analogy to weave throughout your program. Field test your ideas on other park staff, friends or casually with visitors. For issues that may be controversial, Tweed (1988) provides the following advice: "The interpretation of controversial subjects is not fundamentally different from other interpretive efforts, but special concerns do come into play. The most important of these is the rigorous pursuit of accuracy. Information presented by interpreters should always be accurate, of course, but another level of discretion is required here. This discretion needs to come in at least two forms. The first is the careful collection and presentation of certified facts. The second level of discretion unavoidably appears when the time comes to draw conclusions (and especially value judgments) from the facts presented. The concept here is that interpreters should 'plant' problems in visitors' minds, and then let the visitors' minds move independently to value judgment maturity." The tenious nature of the global change issue lends itself well to this strategy.

Interpreting
"What sets critical natural resource issue interpretation apart from other traditional forms is that it focuses more extensively on problems and their solutions" (Whatley and Sikoryak, 1988). From knowledge comes awareness, from awareness comes attitudes, and from attitudes comes behavior. Unfortunately, the links between knowledge, awareness, attitudes and behavior are not perfectly correlated. While many of our interpretive programs suggest an action that visitors may take to learn more about a situation or to promote a certain cause, the follow-through by visitors is often minimal. Critical resource issue programs need to be heavily activity-oriented. While background material is necessary for understanding, much of the other program content can be communicated best in an applied setting. With a large portion of your program devoted to an actual activity, your program will be more enjoyable and visitors will obtain a feeling of accomplishment. Once inspired with the knowledge that they can make a difference, they will be more likely to take positive action.

Evaluating
Consider including pre-assessment, formative and summative evaluation into your interpretive planning process. Two books that are excellent sources for evaluative ideas are *Interpretive Views* (Machlis, 1986) and *On Interpretation* (Machlis and Field, 1991).

Don't worry — be happy! Just get involved in high impact interpretation with heavy activity orientation for results in interpreting critical resource issues for the public.

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Contributed by *Pamela A. Wright*, Simon Fraser University and *John W. Hanna*, Inside-Outside, Inc.

3.7 Global Change and Cultural/ Historical Interpretation

Communicating critical resource issues is of major concern to most NPS communicators. A 1991 study found 82 percent of NPS interpreters who participated in the study felt "critical resource issues are valuable program areas for our visitors" (Mullins and Watson, 1992). Whether the messages and resource impacts are from acidic deposition, loss of biological resources, loss of coastal barriers, global change-related, etc. our messages are impacted. Natural, cultural, historical and recreational resources, whether urban or rural, are all impacted.

All too often critical resource issues are lumped into the natural history interpretation realm because of their ecological data base. Second-level analysis can turn up large human impacts based on resource changes. Such is the case with global change and the cultural and historical programs of NPS.

Global change, the term used for amalgamation of all the potential changes that may result from the overall warming of the earth, has strong potential to influence the future as it has the past. Had the hunters of mastodons at the end of the last ice age been equipped with the global monitoring equipment of today, they very well may have coined the term "global warming." Temperature changes and associated events have shifted human settlement patterns worldwide; many of the desert southwest parks include such messages. Even sites that are more recent can look at 1800s weather records and reflect on how people responded to climate change.

Almost every cultural and historical site in the Service has been or potentially will be impacted by shifts in climatic condition. Recognizing that our visiting publics are hearing messages of climate changes in school, through the mass media and from elected officials, the opportunity exists for all NPS units, where global change is relevant, to weave appropriate messages into existing themes. Because of the ease visitors have in relating to the cultural and historical messages presented by NPS, such sites have an opportunity to expand on both past and potential future climatic changes to more effectively interpret global change in a holistic manner.

Interpreters from throughout the Service provided the following suggestions as program topics for integrating global change messages into existing cultural and historical themes:

- Awareness of what is happening around the world
- Change of structural resources due to acid rain
- Climate change since last ice age
- Coastal flooding and cultural/historical resources
- Compare extinction rates with endangered species
- Compare past and present global conditions
- Conservation/preservation of water resources
- Correlation between culture and climate changes
- Deterioration of non-replaceable resources
- Direct effect on coastal historical sites
- Effect of industrial pollution on park resources
- Focus on human impact
- How global change affects food, shelter and water
- How global change and biological diversity affect all park sites
- How humans have changed the environment over the past several hundred years
- Interpret historical sites' original condition
- Interpret local changes
- Interpret so people can relate global change to their lives
- Medical uses of plants
- More environmental stress on cultural environment
- Native American programs/global change/climate change relationships
- Plants that are affected by pollution/global change
- Presentation and protection of historical sites
- Quality of life issues
- Spaceship earth concept
- Show relevancy to the present
- Tree dating techniques/pack rat middens
- Use of artifacts to interpret changes at the site
- Use preservation theme

(Mullins and Watson, 1992)

The messages are there. The links can be made. The underlying questions seem to be: To what extent do I, the interpreter, make the links? What do I leave out if I include global change? and, Does this message dilute the cultural and historical story the park was established to tell?

3.7 Cultural/Historical...(con't.)

Perhaps this set of questions is no different than the set of questions that surrounds each park, each program and each type of media. Typically, specific themes, goals and objectives are established under the superordinate set of NPS themes, goals and objectives. Interpreters and their supervisors are left to use their professional judgment on how to best format the message. This is the case with global change messages in cultural and historical interpretation; if it is appropriate, include it.

What are the impacts of global change on interpreting the Native American past and present of the southwest? What are the impacts of a radically altered greater Everglades or when we are trying to tell the stories of the Native Americans of the southeast? Does the decline of native rubber tappers in South America have a role in the story of Thomas Edison or the rubber industry in the United States? The answer is unequivocally, yes.

Historical and cultural areas, with all of their tangible objects and with the ease with which we humans of the present can relate to our ancestors, are in an excellent position to foster the interpretation of global change as well as other critical resource issues. Historical and cultural interpretation is housed in environmental imperatives. The bottom line is, will we only interpret the house or will we go the next step and help the visitors understand the foundation of the story. Perhaps more importantly, will we help the visitors understand the environmental foundation upon which our future history is to be built — a foundation that each of us has a hand in building. As we help visitors fully comprehend the past, we can also help them understand their options in influencing the future.

References

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3.8 The Saga of Joe Toolate

Joe was born and raised in the San Francisco Bay area. As a child he visited Yosemite National Park many times with his family. He graduated from the University of California at Davis with a degree in biology/natural resources management.

Year			Years
1997–1999	(GS4)	Joe works as a Seasonal Ranger at Yosemite	2
2000	(GS5)	Joe receives career-conditional appointment at Golden Gate	1
2000–2005	(GS5/7)	Park Ranger — Golden Gate N.R.A.	5
2006–2007	(GS-9)	District Ranger — Cape Hatteras N.S.	2
2008–2010	(GS-11)	Chief Ranger — Great Basin N.P.	3
2011–2014	(GS-11)	Superintendent — Coronado N. Mem.	4
2015–2019	(GS-12)	Chief Ranger — Lassen Volcanic N.P.	4
2020–2023	(GS-13)	Chief Ranger — Great Smoky Mts. N.P.	4
2024–2028	(GS14)	Asst. Superintendent — Everglades N.P.	5
2029–2033	(GS-15)	Superintendent — Yosemite N.P.	5
			35

By 2007 rising sea levels at Cape Hatteras are impacting coastal estuaries with several marine species dying off and being replaced by more southern warm water species. Coral reefs are expanding northward from Florida and will reach the Cape Hatteras area in another 50 years. Several NPS coastal historic sites are being impacted.

By 2010 the last remnant pockets of spruce and fir occur only on the highest elevations of Wheeler Peak, Great Basin National Park. In another 20 years they will be gone.

By 2020 sugar maples are extinct in southern Appalachia and are no longer found in Great Smoky Mountains National Park. Spruce and fir forests are disappearing and deciduous hardwoods are colonizing the former conifer stands. The fall colors are not as spectacular as they used to be with the loss of the maples.

By 2025 about half of Everglades National Park is covered by salt or brackish water due to an almost one foot rise in sea level. Winter-feeding resources for wood storks and many other wading birds have been greatly altered. The visitor facilities at Flamingo have been abandoned.

By 2030 in the Sierra Nevada the oak woodlands are being replaced by chaparral. The oaks are moving upward and replacing the pine and fir forests. While the range of the acorn woodpecker is expanding, that of the northern goshawk and blue grouse is rapidly contracting.

When Joe's grandchildren visit him just before his retirement in 2033, they camp in Tuolomne Meadows. Joe explains to them that this place was once actually a meadow and describs what the meadow looked like. They sleep amid the small but rapidly growing hardwood forest. There is no need for down jackets or sleeping bags. The nights are warm and balmy at the 7000-foot elevation.

By the time Joe Toolate ends his 35-year career, the parks are ecologically different than they were when his career began. And the changes are only just beginning.

An ecological allegory.

Contributed by Richard L. Cunningham, Chief of Interpretation, NPS Western Region.

3.9 Global Change and the Worldwide Decline in Amphibian Populations

Recent concern by many biologists has focused on the apparent worldwide decline of some amphibian species. In February 1990, a two-day workshop was held in Irvine, California, to review the situation. The attending scientists agreed in general that several of the approximately 5,130 species of the world's amphibians are declining at alarming rates. Almost every continent, including North America, has certain amphibian populations undergoing serious decline. Perhaps as many as 15 amphibian species have become extinct. Major losses appear to be occurring in North America, Latin America, Europe and Australia. The declines or disappearances are spotty, with some local populations persisting while others nearby have become totally extirpated. Of particular concern is the decline or extirpation of amphibians living in national parks and equivalent reserves — places where loss cannot bc easily attributable to major habitat change or destruction.

Notice of the amphibian decline began independently in the 1970s, although Edwin Way Teale, in his book *Springtime in Britain* (1970), remarked on the decline and disappearance of frogs in Britain in the 1960s. Some biologists have compared the environmental role of amphibians to the proverbial canaries in a coal mine. Frogs, toads and salamanders may be sensitive indicators to local and to global environmental changes. Because of their position in the food chain amphibians may indicate an early warning system for threats or impacts to the environment.

Several reasons have been speculated for the worldwide population declines. These reasons include greenhouse effects, local climatic changes, drought, increases in ultraviolet light, air pollution, acid precipitation (including acid snowmelt), pesticides, disease, habitat destruction and the introduction of predatory alien fish. The results of a twelve-year study of a pond in South Carolina pointed to drought causing random population fluctuations. Studies of spotted salamanders (*Ambystoma maculatum*) in Massachusetts detected population declines around 1970. Increasing acidity in rainwater and in snowmelt due to acid deposition was suspected of affecting the viability of the salamander's eggs. Both the skin and eggs of amphibians are very permeable, thus allowing chemical absorption.

The amphibian decline may prove to be one of the world's major conservation problems. Amphibian species are even declining in parks and similar nature reserves. This holds true for certain amphibian species in several western United States national parks. At least seven species of frog in the American west are showing population declines: the tailed frog (*Ascaphus truei*), Cascade frog (*Rana cascadae*), red-legged frog (*Rana aurora*), spotted frog (*Rana pretiosa*), mountain yellow-legged frog (*Rana muscosa*), foothill yellow-legged frog (*Rana looylei*) and the Yosemite toad (*Bufo canorus*). About two-thirds of the Colorado Rocky Mountains population of the tiger salamander (*Ambystoma tigrinum*) has recently declined. United States national park areas that have reported amphibian population declines and actual local extinctions include Yosemite, Sequoia, Kings Canyon and Lassen Volcanic National Parks and Pinnacles National Monument.

Northern California and southern Oregon are rich in amphibian species diversity. Mendocino County, California, has 12 species of salamander. About 62 amphibian and reptile species live in the Klamath Region of Oregon and California. This area is a mix of more northern amphibians and more southern reptiles (which are moving northward). East of the Klamath Region is the Great Basin. Global change could create habitat suitable for Great Basin reptiles to move westward towards the Oregon and California coasts. Several Pacific northwest amphibians, especially salamanders, are relict or endemic species. The Shasta salamander (*Hydromantes shatae*), first discovered in 1950, is found only in the vicinity of the Shasta Reservoir headwaters near Whiskeytown National Recreation Area, California. The closely related limestone salamander (*Hydromantes brunus*), discovered in 1952, occurs only near Yosemite National Park, in the Lower Merced Canyon of Mariposa County, California. A third example is the

3.9 Worldwide Decline..(con't.)

Mount Lyell salamander (*Hydromantes platycephalus*), which occurs in the Sierra Nevada Mountains south to Sequoia National Park.

On a global basis the beautiful golden toad (*Bufo periglenes*), once abundant in Costa Rica's Monteverde Cloud Forest Reserve, has now virtually disappeared. The gastric brooding frog (*Rheobatrachus silus*), discovered in the rain forests of southeastern Australia in 1973, had completely disappeared by 1981. Approximately ten percent of the other 193 Australian frog species are also showing population declines. Since 1987 several species of toads have vanished from seemingly pristine habitat at elevations over 10,000 feet in the South American Andes. Why? Speculation here centers on increased levels of ultraviolet radiation.

The decline and disappearance of frogs, toads and salamanders from global aquatic ecosystems will have many ecological ramifications. Amphibians are significant members of food chains, being both important prey and predators. Long-term ramifications of the loss of amphibians from the aquatic and semi-aquatic ecosystems where they live are unknown. At the minimum, our world will experience more examples of diminishing biological diversity. Rachel Carson's famous call to environmental awareness in *Silent Spring* (1962) dealt with a spring silent of birds. Now, perhaps due to different locations, there may be springs silent of the calls of many familiar frogs and toads, as an audio curtain descends upon these change-sensitive amphibians.

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Contributed by Richard L. Cunningham, Chief of Interpretation, NPS Western Region.

4.1 The Earth's Radiation Balance

The heat we get from the sun provides energy for all living things on Earth. Green plants use the sun's energy in photosynthesis, and ultimately store the energy in ways that it is available for use by all other living material. Radiation from the sun also plays a critical role in determining the climate in which living creatures on Earth function.

The Earth's radiation balance depends on radiation received from the sun, gases in the atmosphere that react with radiation, as well as water vapor and other particulate matter in the atmosphere. In turn, the radiation balance determines the Earth's climate. If the Earth system worked solely on the premise that "what comes in must go out," we would not survive on this planet. The heat that the sun gives us alone is not enough to keep us warm. But the atmosphere magnifies the heating effects of the sun by absorbing energy and warming the lower part of the atmosphere.

When the actual temperature that the planet should be, based on the heat it radiates into space, is calculated, it is found that the globe should be a "frozen wasteland, colder today by about 33 degrees Celsius (60 degrees Fahrenheit) on average" (*Report to the Nation On Our Changing Planet*, 1991). The atmosphere, with its heat trapping capabilities, saves us from such a fate. Special trace gases, called greenhouse gases (carbon dioxide, ozone, methane, water vapor and nitrous oxides), act naturally like the glass of a greenhouse by trapping heat within the atmosphere, rather than letting all of it bounce off the Earth and back into space. What originally comes into the atmosphere is partially absorbed by the Earth; most is reflected back out toward the sun. The energy reflected back outward, as the surface of the Earth absorbs radiation, is like the heat we feel sitting next to a campfire. However, the greenhouse gases capture, absorb and reflect back toward Earth again some of that outgoing radiation and warm the part of the atmosphere that we live in even more.

The temperature that we have adapted to will change if shifts occur in either the amount of sunlight the Earth receives, the amount of sunlight the Earth reflects or the extent to which the atmosphere retains the energy from the sun.

In recent years, it has become evident that human activities that are adding excessive greenhouse gases to the atmostphere may be affecting the radiation balance that determines our climate. The extent of those possible changes is not yet evident, since there is a "lag time" for the Earth to react to continuous changes in its heating system. Once the sun's energy reaches the Earth and is captured by the atmosphere, it takes time for the absorption of heat by the Earth and the warming of the atmosphere to adjust to the amount of heat within our "greenhouse." The Earth's radiation balance must continuously seek an equilibrium condition in which the radiation received, reflected and retained balances with the absorption and warming of the Earth's surface (land and water) and the air around it. Since the described "greenhouse effect" of the atmosphere is a natural and necessary part of the Earth's radiation balance, it is important now to discover how the balance, along with climate, is changing, as well as what is causing such changes.

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Fact Sheets

4.2 Greenhouse Gases

The Earth's atmosphere is almost entirely composed of nitrogen (78 percent) and oxygen (21 percent). But the remaining one percent of atmospheric gases, called trace gases, plays an extremely important role in allowing life to exist on Earth. They are responsible for controlling the Earth's temperature. These gases easily allow earth-bound solar energy to enter the atmosphere, but less readily allow outgoing energy to escape. These special trace gases are called "greenhouse gases" because, like the glass of a greenhouse, they absorb or reflect heat that is escaping, and hold it within the atmosphere (or greenhouse) to cause general warming of the Earth's surface.

Many greenhouse gases exist in the atmosphere naturally. Without them, the Earth would be a frozen mass. Carbon dioxide, ozone, methane, nitrous oxides and water vapor are the major naturally occurring greenhouse gases. While natural processes such as the eruption of Mt. St. Helens and forest fires contribute gases to the Earth's warming blanket, concern has been expressed about the increase in greenhouse gases due to human activities. Humans have introduced chlorofluorocarbons (CFCs) into the atmosphere through the use of refrigerants for air conditioners, solvents for manufacturing processes and foam insulation. And some of these CFCs are known to absorb heat in the atmosphere as much as 10,000 to 20,000 times more effectively than carbon dioxide, which is currently considered the largest contributing gas to greenhouse warming (*Policy Implications of Greenhouse Warming*, 1991). This means that it takes 10 to 20 thousand molecules of carbon dioxide to have the same warming effect of only one molecule of chlorofluorocarbon.

Besides introducing new types of greenhouse gases to the atmosphere, humans have increased the rate of emissions of some naturally occurring greenhouse gases. For example, carbon dioxide levels in the air are now 25 percent higher than preindustrial (1750–1800) levels, and are higher than at any time in at least the past 160,000 years. Much of the change can be directly related to human activities such as burning gasoline, oil and wood (*Climate Change, The IPCC Scientific Assessment*, 1990). The concentration of methane, another greenhouse gas that occurs naturally, has also been affected by human activities; methane is now more than double preindustrial (1750–1800) levels (*Climate Change, The IPCC Scientific Assessment*, 1990). Practices such as the cultivation of rice paddies, use of landfills and domestication of cattle (which release methane during their digestive processes) emit added methane that may be contributing to the concentration increase.

Greenhouse gases have properties that make projections about global warming especially difficult. Many greenhouse gases can exist in the atmosphere for decades or centuries. For example, it is estimated that some CFCs will remain in the atmosphere for 130 years, while the effects of carbon dioxide emitted into the atmosphere may take between 50 and 200 years to be felt (*Policy Implications of Greenhouse Warming*, 1991). Thus, the gasoline burned in a car or the CFCs released by using a leaky air conditioner today may very well affect the climate that our great-grandchildren's great-grandchildren live in. This property of greenhouse gases makes their atmospheric concentrations very slow to respond to changes in emission rates. Because there is a time lag between the emission of greenhouse gases and the realization of their effects within the atmosphere, we may already be committed to substantial warming.

Increased concentrations of greenhouse gases in the atmosphere will affect the Earth's climate in questionable ways. If all other factors were held constant, it could be confidently assumed that temperature would rise as did the concentration of greenhouse gases since the atmosphere would more efficiently absorb energy and produce global warming. But many other interactions and secondary changes may also result. One change may spark another that has not been explored, or one change may produce unexpected effects when combined with another change. For example, during a blustery winter night in Rocky Mountain National Park, we expect our room to become warm when we turn on a portable heater. But if the windows are simultaneously opened, we may see little or no effect, or even the opposite of the expected warmth. Because of the complex interaction, modeling is difficult, yet most models support the position that gradual warming as the result of existing and future greenhouse gas concentrations can be expected.

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Fact Sheets

4.3 Carbon Dioxide

Although the effects of interactions between greenhouse gases in the atmosphere are still largely uncertain, the way that most greenhouse gases behave independently is relatively well understood by chemists and physicists. The exception to this understanding is carbon dioxide (CO_2). Ironically, the gas that is least understood by the scientific community is the largest contributor to global change — accounting for 50 percent of projected warming (Byrne, 1989).

Carbon is the element of life. Animals exhale it as CO_2 and plants use it for the production of energy and biomass. All living material is made of at least some carbon. The element is cycled between the atmosphere, oceans and other surface water, sediments and rocks and living organisms. The largest exchanges of carbon occur between the atmosphere and water on the Earth's surface, as well as between the atmosphere and plants and animals. These exchanges of carbon most commonly occur in the form of CO_2.

Scientists know that CO_2 traps heat in the atmosphere. And that CO_2 emitted into the air today will influence the atmosphere's concentration of the gas well into the future because of the long length of time it takes for the CO_2 in the air to adjust to a new equilibrium with the water and living organisms. Similarily, when milk is poured into a hot cup of coffee, it takes time for the milk to completely mix in with the coffee if left unstirred. The original black coffee and the final lighter product reach an "equilibrium" relatively quickly. When mixing takes place, the milk and coffee move around one another in order to be as well distributed as possible (or in "equilibrium"). This is a long, slow process in terms of CO_2 diffusion into the total air mass.

It is believed that about 40 percent of the CO_2 that is released into the air stays in the atmosphere for many years (decades or even centuries), and about 15 percent is incorporated into surface water or living material (*Policy Implications of Greenhouse Warming*, 1991). Some evidence suggests that the waters and biota use the gas in roughly equal proportions, but this still is not well understood. The most uncertainty, however, comes when scientists look for the remaining 45 percent of the CO_2 that is released into the air but is neither detected in the atmosphere nor detected in the Earth's waters and living material. Where does it go? You would feel the same frustration that scientists studying the phenomenon feel if you were conducting a program in a sealed room of 100 people, and when you turned your back 45 of them just disappeared!

Why is the level of CO_2 in the atmosphere increasing? "New" carbon cannot be created. Two human processes have been primarily responsible for moving carbon from one part of the carbon cycle to another: fossil fuel combustion and changes in land use such as deforestation. Fossil fuels are actually made of material that used to be alive; therefore, as in living organisms, they contain significant amounts of carbon. By burning fossil fuels, such as coal, oil and gas, carbon is released into the air in the form of carbon dioxide. Similarly, when forests are cleared and the wood is burned or rots, carbon that was once essential to the life of the trees is released into the air. The clearing of forests also indirectly contributes additional carbon to the atmosphere because with deforestation there is less vegetation to absorb CO_2 for photosynthesis.

The atmospheric concentration of CO_2 is now about 25 percent greater than the preindustrial (1750–1800) concentration, as well as higher than at any time known in at least the last 160,000 years (*Climate Change: The IPCC Scientific Assessment*, 1990). If we continue to release CO_2 into the air at present rates, the concentration could double the preindustrial level by the year 2050.

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Fact Sheets

4.4 Ozone

Ozone is a major issue in environmental well-being. Discussions are usually framed in terms of the "ozone hole" and associated dangers of ultraviolet light. It is true that the upper atmosphere is losing ozone and thus leading to the phenomenon know as an ozone hole. But the lower atmosphere is gaining ozone that is capable of trapping heat into the Earth's atmosphere just as other greenhouse gases.

An ozone hole is a phenomenon caused by the depletion of ozone in the outer layer of the Earth's atmosphere called the stratosphere. Within the stratosphere, ozone functions to keep ultraviolet light rays, which can cause skin cancer and eye damage, out of the Earth's lower atmosphere. Ozone, which is present in the Earth's troposphere, does not keep out harmful rays. Instead, it functions to hold heat inside of the Earth's atmosphere.

Ground-level ozone is often called "bad" ozone, tropospheric ozone or "smog." It is formed when emissions from automobiles, power plants and industrial processes react in the presence of sunlight (Byrne, 1989). Besides being an important greenhouse gas, ozone at ground level can be harmful to plant and animal tissues. However, not all ground-level ozone exists because of human activities — some occurs naturally and is transported down close to the Earth (into the troposphere) from the higher layer of the atmosphere.

Ozone (O_3) is not uniformly distributed throughout the atmosphere like other gases. While O_3 only exists in the lower atmosphere for a few weeks at the most, its concentration varies with altitude, latitude, longitude and season. For example, the ground-level O_3 concentration peaks in the United States in the spring and summer months; there is a yearly average of 35 percent more O_3 in Portland, Oregon, and the Adirondack Mountains than in Melbourne, Australia, and the Pampas region of Argentina due to latitude differences (Logan, 1985).

Ozone's potential to contribute to global warming depends on where it is within the atmosphere. If it resides in the troposphere, or close to the Earth's surface, it may contribute to greenhouse warming because it functions as a greenhouse gas. If it resides in the stratosphere, it does not act as a greenhouse gas and is not thought to contribute to worldwide temperature increases. However, the sporadic data available suggest that the concentration of surface level O_3 is increasing at a rate of 0.5 to 1 percent per year (Logan, 1985). Overall, ground-level ozone's continually changing concentration leaves its impact on climate difficult to pinpoint (Edgerton, 1991). While there are still questions to be answered, it is believed that the net effect of increasing ground-level ozone is global warming.

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Fact Sheets

4.5 Chlorofluorocarbons

Chlorofluorocarbons (CFCs) do not exist naturally. While CFCs did not exist a century ago, their concentrations now grow at about 5 percent every year (Byrne, 1989) and account for 24 percent of projected warming (Edgerton, 1991). While CFCs make up only a small percentage of the greenhouse gases by volume, they contribute substantially to global warming because one molecule of a CFC has the warming power of 10,000 to 20,000 molecules of carbon dioxide (*Policy Implications of Greenhouse Warming*, 1991).

There are several different types of CFCs. The general term "chlorofluorocarbon" is used to describe an entire family of human-made molecules that contain carbon and either chlorine or fluorine. These kinds of molecules have special characteristics that have placed them in high demand in our society. CFCs are made exclusively by industrial activities and have a wide range of uses such as in refrigeration and air conditioning, semiconductor manufacturing, degreasing solvents and foam insulation. Unfortunately, most CFCs produced eventually end up in the atmosphere.

However, future emissions of CFCs will probably be significantly reduced or even eliminated as a result of national and international efforts. The Montreal Protocol and the Clean Air Act both call for a phase-out of CFC production, although they do not stop the use of existing CFCs or try to eliminate CFCs before they are released into the air. While these government actions can have positive effects, they will not eliminate the threat of CFCs as greenhouse gases. The atmospheric concentrations of CFCs will be significant for at least the next century because CFCs remain in the atmosphere for about 100 years after being emitted. In addition, many of the substitutes for CFCs that are being used are also greenhouse gases.

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4.6 Changes in the Earth's Climate?

Climate is naturally variable. Skiing in the Rockies is better some years than others. Farmers suffer the effects of droughts unexpectedly. However, a trend of warming temperatures has been established in the last century. In fact, five of the warmest years in recent history occurred in the 1980s. Even though evidence already shows that there has been a one degree Fahrenheit rise in global temperature over the past century (Edgerton, 1991), it is difficult to prove that the trend is due to greenhouse gases. Nonetheless, most scientists believe that human activities are at least partly responsible for the current warming.

Computer model estimates indicate that the increase in greenhouse gases between 1850 and 1980 have committed the planet to an equilibrium warming of 1.3 to 3.7 degrees Fahrenheit (Ramanathan, 1987). This means that the Earth may experience at least this amount of overall warming regardless of what we do now — even if we totally stopped emitting greenhouse gases into the air today. The slow adjustment of the oceans to the new atmospheric temperatures (called thermal inertia) moderates the effects of warming in the short term.

Estimates hold that if current trends continue, we will have achieved a doubling of the preindustrial levels of CO_2 in the atmosphere by the year 2030 to 2050 (*Policy Implications of Greenhouse Warming*, 1991). Such concentrations could commit the Earth to a 3.6 to nine degree Fahrenheit temperature rise. Although we will not be able to detect these warmer temperatures when the doubled concentration levels are first reached, the increases will be inevitable. In Washington, DC, the average number of days with temperatures over 100+ degrees would increase from one to 12 per year. And in Omaha, Nebraska, the average number of 100+ degree days would increase from three to 20 per year.

Generally, it is thought that global warming will cause current climatic regions to shift toward the poles. For example, the desert of the American southwest would replace the grainbelt — which would in turn shift northward into Canada. Shifts alone would not necessarily be considered so undesirable. But the rate of the shifts may cause difficulty for animals and plants to migrate along with the changing temperatures. The barriers that humans have put in the way must also be taken into consideration. While the climate may allow the best wheat farming in parts of current deciduous forests, it may not be easy to move towns and cities in order for farms to be established. Likewise, the soils that are present in deciduous forests have characteristics that have developed because of the biological and physical elements in those regions. And those characteristics may not be conducive to certain large-scale agricultural practices.

If warming continues as predicted, temperature increases in polar regions will be several times greater than the global average rise. This will lead to more uniform global temperatures at any given time (*Policy Implications of Greenhouse Warming*, 1991). Most models predict that glaciers will melt and increase the amount of water available for the seas and for evaporation. Even though global temperatures have risen in the past century, it has been observed that the Greenland ice sheet is actually getting thicker. The contradictions complicate building predictive models.

With warmer temperatures, more water will evaporate. The predicted rise in global evaporation would also lead to more precipitation (Hillel and Rosenzweig, 1989). Even though an overall increase in rain, sleet and snow can be expected, differing wind patterns and circulation patterns will cause some areas to be wetter while others (probably the interiors of continents) will be drier (Hillel and Rosenzweig, 1989). The overall increase in temperature will also increase the probability of extreme events such as droughts and torrential storms. We may see Hot Springs National Park in Arkansas suffer from the lack of water, while the Everglades National Park in Florida is battered by recurring storms.

Global warming and associated changes are not givens. Nonetheless, serious scientific attention is being paid to the concept.

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Fact Sheets

4.7 Changes in the Oceans?

Compare the winter temperatures in San Francisco, California, to those of St. Louis, Missouri. Even though they are about the same distance from the equator, the winters in San Francisco are much milder because of the Pacific Ocean. The oceans react to changes in the amount of heat available very slowly compared to the air's reaction. When the sun shines brightly, the air heats up quickly, but the waters off the coast of Maine are still too cold to swim in long after people have begun to wear summer apparel.

How fast oceans heat up or cool down is unknown. We know much less about the way the oceans work than about the atmosphere. The water on the surface of the oceans is able to transfer heat with the atmosphere much quicker than the surface water is able to transfer heat with the deep ocean waters. It takes longer for the water at the surface to mix with the deep water so that the heat can be "diluted" or spread out more evenly through all of the water.

The dilution process is based on variations in the water's salinity and temperature. This is similar to pouring cherry syrup into soda water; the syrup sinks to the bottom of the glass. Besides making a great "Shirley Temple" cocktail, you have just demonstrated why ocean waters move in patterned currents. Just like the syrup, colder, salty water sinks to the ocean floor while warmer, fresher water floats on top like the soda. The deep water near the poles is even colder and saltier than the deep water near the equator. Because of their different densities, the water near the poles spreads out on the bottom of the ocean and moves toward the equator. This causes the waters above to move also. Thus, ocean currents are created.

In the history of the Earth, major changes in ocean currents have affected the oceans' ability to absorb CO_2. Because of this capacity for absorbing, oceans are often called "CO_2 sinks." Past glacial and interglacial periods have shown that the amounts of CO_2 in the air have varied greatly. It is thought that such variations in carbon dioxide concentrations may have been due largely to changes in ocean circulation (*Climate Change, The IPCC Scientific Assessment*, 1990). If the ocean currents change in response to global warming, their ability to absorb CO_2 and hold heat may either increase or decrease. Therefore, they may either reinforce the effects of global warming if they change such that they can hold less heat; or they may slow the effects of the temperature rise if they shift and can hold even more heat and CO_2.

Ocean temperatures will eventually rise if long-term global warming becomes a reality. One theory holds that ocean temperatures will reach a certain level at which the oceans will no longer be able to hold more heat. Once this "threshold" temperature is reached, it will trigger sudden shifts in the way ocean currents all over the world flow (Broecker, 1987). In turn, such changes in currents will further complicate modeling long-term effects of global change.

Ocean temperatures are also thought to determine storm patterns. But the way that storm patterns would change is unknown. While the people, plants and animals of southern Florida are accustomed to the frequent hurricanes that spin onto the land from the Atlantic Ocean, such powerful and recurrent storms in Los Angeles or New York City would certainly be surprising.

The ocean currents may also be affected by fresh water from melting glaciers that runs off into the oceans. When glaciers melt and global waters slowly mix, the temperatures of the oceans become more uniform. The temperatures of the Caribbean Sea and the Greenland Sea, while they will still be very different, will be more similar than they are today. The change in the concentration of salt in the water, along with the more uniform temperatures, could cause major ocean current shifts (*Policy Implications of Greenhouse Warming*, 1991) as well as bring about major changes in the makeup and distribution of marine life.

The exact role that the oceans will play in a world of global warming is still unclear, but they will play a major role. As the possibilities of global warming are explored, oceans will continue to play a major role in global change research.

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Fact Sheets

4.8 The Problem of Prediction: Feedback

One of the most difficult aspects of predicting global change is that of "feedback systems." A positive feedback system is like a snowball rolling down a hill in a cartoon. Once it starts rolling, it gets bigger and bigger as it picks up snow. The snowball rolls faster and faster as it gets bigger, allowing it to get even faster and bigger. The initial act of rolling the snowball sets in motion a feedback system that enhances its speed and size.

There are also negative feedback systems, like a fire safety switch on an electric heater. When the heat rises above a set temperature, a mechanism is set into motion that turns the heater off. Thus, the safety system counteracts the effects of the high temperature.

These types of feedback will affect the occurrence of global change. The greenhouse effect (the warming of the Earth's surface due to gases in the atmosphere that hold in heat) is a natural phenomenon — we would not be able to survive on this planet without it. But the impact of human activities that affect the concentrations of greenhouse gases in the atmosphere are unpredictable in light of feedbacks. Without feedbacks, we would assume that if the concentration of greenhouse gases increases, predictable temperature increases would follow. But the many complex interactions that occur once the process of warming has begun leave us without good, consistent predictions about what will happen to our climate in the future. Temperature changes will cause many other subsequent changes that may either enhance or counteract warming. If natural or human events cause temperatures to change, feedback responses are inevitable — but we do not know whether the net result will enhance or counteract global warming.

If temperatures rise, increased evaporation will cause more water vapor to exist in the air. Water vapor is a greenhouse gas, and can thus cause even more warming. Another positive feedback response may occur as glaciers melt and methane (CH_4) that has been trapped in the ice is released. Released methane would add to the concentration of greenhouse gases in the atmosphere and may lead to more warming. It is hard to predict how much warming would be enhanced by these types of positive feedback, or whether they would be totally countered by negative feedback systems.

If temperatures rise and increased evaporation causes more water vapor to exist in the atmosphere, the added vapor may generate more clouds. Extra cloud cover could act as a giant parasol, "shading" the Earth by reflecting sunlight back out toward the sun before it enters the lower atmosphere. Another possible negative feedback system that would buffer or counter the effects of global warming may be related to the Earth's "albedo" — or the Earth's "reflectivity." Since ice reflects large quantities of light, it has a high albedo. Conversely, blacktop in a parking lot, which does not reflect much light, has a low albedo. If temperatures rise and glaciers melt, the Earth's albedo would be altered. The surface of the planet would absorb more light and heat, so the atmosphere would not heat up as much as might be expected. And still another possible negative feedback system that could counter global warming may arise from the shifting of ocean currents. If increased temperatures cause the ocean currents to change directions, then the ability of the oceans to absorb CO_2 from the atmosphere could be greatly increased. Therefore, the concentration of greenhouse gases in the air, and the atmosphere's ability to hold in heat, would be reduced.

The existence of feedbacks in the Earth's climate system is certain, but their power to have an impact on climate change is uncertain. Whether the overall effect of feedback systems, in the event of global warming, would ultimately increase, decrease or not affect temperatures is unknown and demands further study.

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4.9 Predictions by Computer

Our climate is created by a complex web of the sun's heat, wind patterns, ocean currents and numerous other natural elements. Some of the interactions between these elements seem basic and are easily understood. For example, when the sun shines more directly on the Blue Ridge Parkway in the summer months, temperatures generally rise. But when we ask exactly how much warmer the temperatures will be at Channel Islands National Park during the next summer season in order to project visitor attendance levels, the interactions become more complex. The elements that influence climate chaotically mingle to yield the environment we experience. If we could isolate each factor that influences climate and determine the degree of its influence, predictions about the future would be easy to make, and cause and effect relationships would be relatively easy to determine. However, isolating any one influence on climate is impossible because they all weave together like a spider web with complex interactions.

Recently, scientists have begun to use computer models to simulate the interactions that are thought to take place. Models are intended to be simplifications of the real world. They treat the factors that influence climate as physical entities which obey basic laws of chemistry and physics. But the models are extremely complex. Climate models take into consideration much more than the air, Earth and oceans; they also try to simulate the effects of chemical elements and organic debris in the soil, water vapor and other gases in the air, salt and oxygen in the oceans, and biological systems. While the models try to be comprehensive, no one is really sure of whether or not there is some other factor that has long been overlooked or whether the models have been relying too heavily on a factor(s) which is relatively unimportant in influencing climate.

In addition to the limitations caused by scientific uncertainty about what influences climate and by how much, "global climate models" (also called "general circulation models" or GCMs) are limited by their inability to deal with small geographic areas. The models "slice up the atmosphere and oceans into thousands of grid boxes and calculate how the weather changes in each box" (*Report to the Nation On Our Changing Planet*, 1991). Each grid is generally very large. The average square is 300 miles on each side — about the size of the state of Wyoming (*Global Change in the Great Lakes*, 1992). Within such a large area, we know that climate can vary widely. Unfortunately, current computer models are unable to be much more specific.

Yet another limitation for GCMs arises because the Earth's climate varies naturally. Without any influence from human activities, global temperatures vary from year to year. These natural fluctuations make it difficult for scientists to detect which changes are truly threats to the Earth's climate balance and which are natural random events.

Many GCMs make projections about the effects of doubling of the level of carbon dioxide that was in the air before the industrial revolution (1750–1800). However, these projections are not based solely on CO_2. While researchers talk mainly in terms of carbon dioxide, the models address the effects of an atmosphere with any combination of greenhouse gases in such concentrations that would have the same greenhouse effect of holding heat as a doubled preindustrial level of carbon dioxide. The projected date when the levels of greenhouse gases in the air will reach twice the preindustrial level of CO_2 is between the years 2030 and 2050 (*Policy Implications of Greenhouse Warming*, 1991).

Current models tell us that the Earth's climate could become considerably warmer in the future if the concentrations of greenhouse gases in the atmosphere continue to rise. There may be an average temperature increase of 1.9 to 5.2 degrees Celsius (or 3.4 to 9.4 degrees Fahrenheit) (Hillel and Rosenzweig, 1989; *Policy Implications of Greenhouse Warming*, 1991).

Unfortunately, we do not know how much we should rely on our models because we are uncertain about their accuracy. Since models cannot tell us any definite answers about climate change, why should

4.9 Predictions (con't.)

we even bother with them? The same could be asked about local weather forecasts. The weather person on the evening news may forecast rain for the following day. We know, however, that the weather forecast is not always accurate — we may get a beautiful day of clear sunshine. Although we are not sure about the accuracy of the weather person's rainy outlook, we still watch and use the information when we plan what we will wear and what we will do the following day. The same is true for computer generated climate models. While GCMs are still unable to predict with great accuracy or prove cause and effect relationships, they still offer a framework in which to plan for the years to come.

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4.10 Global Change in the Earth's History

In predicting how climate may change in the future, it is possible to look to the past. Data on past temperatures and climates are available through actual recorded observations for only the past 100 years. However, tree rings reveal evidence of past growing conditions that resulted from differing climates further back in time. Ice cores from glaciers captured the air when they originally froze hundreds or thousands of years ago, and now can provide information about past climates. Rocks can tell the story of past local and global climate through patterns of weathering, as well as with fossils or entombed pollen.

The Earth's temperature record has certainly had its ups and downs. The warmest period we know of was about 100 million years ago near the end of the reign of the dinosaurs during the Cretaceous period. Temperatures were as much as 18 degrees Fahrenheit higher than they are today. Sea level rose as glacial ice melted, and North America was virtually split into two masses of land by a huge sea. Why such elevated temperatures occurred is not known for sure, but there is speculation that they resulted in part because of volcanic activity that spewed large amounts of carbon dioxide (CO_2) into the air during that period (*Report to the Nation on Our Changing Planet, 1991*) or a possible meteor impact that led to a shift in the atmosphere.

Temperatures cooled slowly until about two million years ago, when the Earth began to experience a series of small ice ages. The last ice age ended about 18,000 years ago. Temperatures were about nine degrees Fahrenheit cooler than today, and ice that formed during those cold periods shows that levels of CO_2 and CH_4 (methane) in the air were much lower than those that exist now. This has led to some speculation that the cold times may have been experienced because of the lower concentrations of greenhouse gases. Why would the concentrations of these gases decrease? It is possible that an unexplained reorientation of the ocean currents may have greatly increased the water's capacity to absorb CO_2 so that less carbon dioxide was in the atmosphere. And when ice began to form because temperatures were dropping, CH_4 was trapped in the new glaciers and ice sheets.

More recently, the Little Ice Age, from approximately 1400 A.D. to 1850 A.D., registered average temperatures about 1.8 degrees Fahrenheit lower than today. The temperature decline is thought to have been caused by either volcanic dust that "shaded" the Earth by blocking out the sun's rays, or another type of unexplained variation in the amount of sunlight the Earth received.

The causes of past climate changes have been broken down into three categories (Dickinson and Cicerone, 1986). First, variations in the sun's output or the amount of sunlight that reaches the Earth because of the Earth's orbit can influence global climate. Second, "catastrophic" events such as the eruption of Mt. Pinatubo or meteorite impacts that have been hypothesized to have occurred in the Earth's history can change temperature and climate. A "catastrophic" event, however, does not necessarily imply a "natural" event. Human activities can also be considered catastrophic, as in the case of the oil well fires in the Middle East that followed the Persian Gulf War. Such an event resulted from human activities, but was "catastrophic" in the sense that it had the potential to influence the world's climate. And third, global climate change can result from ongoing biological processes such as photosynthesis, which uses up CO_2.

So while our uncertainty about what will happen to our climate in the future can be lessened by looking to the past, there is still much to be learned and understood about why historic changes have occurred. Such a deeper understanding will serve us in two ways. First, it will provide an effective way of seeing how the climate system works in the real world, taking into account interactions and feedback mechanisms; and second, it will allow us to more fully consider whether recent climate fluctuations have been influenced by human interference.

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4.11 El Niño

For almost as long as history has been recorded, it has been recognized that amazing things happen to the Earth every two–seven years in the coastal zone of Peru — "First of all, the desert becomes a garden... The soil is soaked by the heavy downpour, and within a few weeks the whole country is covered by abundant pasture" (Murphy, 1926). The years in which such events occurred were called the years of abundance by Peruvians, for their country would reap the benefits of increased rainfall and especially moderate temperatures during those special years. It was also noted that a warm ocean current accompanied the plentiful years. The warm water current was named El Niño (meaning the child Jesus) because it seemed to appear close to Christmas.

But what was one country's blessing was another's burden. While Peru experienced the years of abundance, droughts were drying out countries in the western Pacific, and torrential downpours were drowning others in the eastern Pacific. These interconnected global phenomena are caused by El Niño — a special phase of what is called the Southern Oscillation.

The Southern Oscillation is a complex oceanic current and wind pattern that occurs in the southeastern Pacific Ocean. Warm surface water temperatures of the oceans are accompanied by weak westward flowing winds along the equator (called the Trade Winds) and cooler surface temperatures coexist with strong Trade Winds. The Southern Oscillation is the continuous cycling from one scenario to the other. While oceanographers explain the natural cycle in terms of wind changes, meteorologists attribute the wind variations to changes in the ocean (Leetmaa, 1989). At best, it can be said that the interplay of the oceans and the atmosphere cause the Southern Oscillation. The phenomenon known as El Niño is an unexplained exaggeration of the warm water/weak wind phase.

In 1983 and 1987, El Niño was associated with droughts in the western tropical Pacific and floods in the eastern tropical Pacific. But since the weather in the South Pacific is part of an interrelated, complex system of weather around the globe, it is thought that the scope of El Niño's effects are global rather than restricted to the Pacific and its borders.

The other extreme of the Southern Oscillation, characterized by cooler ocean surface waters and strong Trade Winds, is called La Niña. It too has caused far-reaching weather variations in recent years. In 1988, for example, an exceptionally intense La Niña contributed to the drought over North America (Trenberth, et. al., 1988).

How is El Niño related to global change? If warmer global air temperatures result from the greenhouse effect as predicted, the surface waters of the tropical Pacific may also warm. As of now, it is only clear that warm ocean waters and weak westward flowing winds occur simultaneously during an El Niño phase of the Southern Oscillation. Whether the phase is spawned by either the warmer water temperatures or weaker winds is still a mystery to scientists. If, however, warmer temperatures are somehow responsible for triggering an El Niño event, there is need for concern.

There are no conclusive answers as to how global temperature change may affect the Southern Oscillation, or specifically, El Niño; but in an interrelated system such as the Earth's climate system, some effect is expected. As research continues to explore El Niño's sensitivity to global warming, the possibilities of aggravating the phenomenon cannot be ignored when assessing the possible outcomes of global change.

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4.12 Sea Level Rise

Sea level at any given place and time depends on the amount of water available for the seas globally combined with the up and down movements of land. Land can rise and fall because of the movement of the Earth's crust, or because the crust becomes heavier or lighter for some reason. When there is excessive fluid withdrawal from a large area, for example gas, oil or water, the land may become lighter and rise as it "floats" on the "liquid magma" underneath. When massive glaciers grow and move, they may make areas "sink" into the liquid rock. Currently, the sea level in Alaska is dropping because the Earth's crust is being uplifted there as two different pieces of the Earth's crust slowly crash into one another. At the same time, Louisiana is experiencing a sea level rise because, as the Mississippi delta grows larger, extending into the Gulf of Mexico, the piece of the Earth's crust it sits on is getting heavier and sinking.

Global sea level depends on how much water is in the oceans. If global warming continues as projected, glaciers will probably begin to melt and more water will be added to the seas. Additionally, sea level may rise because, as temperatures rise, the water already in the oceans will undergo "thermal expansion." Just like the air in a balloon that expands in the sun and contracts in an air conditioned room, the waters on the surface of the oceans will begin to expand if temperatures rise. The overall effect of thermal expansion, however, will depend on the rate that the water mixes with cooler deeper waters and the rate at which temperatures rise.

Over the past 100 years, global sea level had been increasing at a rate of one to two millimeters per year (Gornitz, et.al., 1982). Some studies suggest, but do not prove, that the rise is due to temperature increases. However, there is some confusion. When we imagine that temperature increases have caused the sea level to rise, we think that it is because glaciers have melted and more water has run off into the oceans. But evidence shows that the Greenland and Antarctica glaciers are actually getting thicker. The two largest glaciers in the world do not appear to be contributing excess water to the oceans. This finding makes it difficult to say that sea level rise in the past 100 years is due to glacial melting.

Current forecasts are for sea level to rise anywhere from zero to 24 inches by the middle of the next century (*Policy Implications of Greenhouse Warming*, 1991) if current warming trends continue. Much of the uncertainty about these estimates is due to the lack of scientific understanding of the interaction between the oceans and the atmosphere. But in order to plan wisely, a rise of more than one foot by the year 2050 is anticipated by scientists (Edgerton, 1991).

Wetlands that are wet only occasionally or have very shallow water systems would be destroyed as water flooded them. Some projections estimate that the Florida Everglades could be completely lost within the next 30 to 40 years (Byrne, 1989). And coastal barriers (islands and other landmasses along the coast line that are formed like giant sand bars) such as the Outer Banks of North Carolina would be covered by water. Coral reefs would also be destroyed as they are "drowned" by rising sea levels. They need to be near enough to the surface of an ocean so that adequate sunlight reaches them. The process of photosynthesis must be able to go on so that the organisms of the ecosystem have food. As the water gets deeper, the sunlight is less able to penetrate the water to the reef and eventually the reef dies.

It is natural for sea levels to fluctuate. In the past wetlands, coastal barriers and coral reefs have been able to migrate along with the moving coastlines and water levels because sea levels changed slowly over thousands or even millions of years. The magnitude of change that is predicted by some for the next 50 to 60 years has never occurred in such a short period of time. The ability of wetlands to migrate inland with the shoreline is doubted because it takes many more years than would be allowed for such complex ecosystems to move, and existing human barriers such as shopping malls and hotels are in wetlands' paths. Coral reefs and coastal barriers would face the same time constraints and possibly even some human barriers to their movement to new areas.

While the certainty and extent of sea level rise is questioned as of now, the possibility is real. In light of the seriousness of the consequences that would follow, the possibility cannot be ignored.

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4.13 Agriculture

Agriculture is important to American industry. As of 1990, agriculture accounted for more than $43 billion in exports, as well as provided ample amounts of food for people living in the United States (*Report to the Nation on Our Changing Planet*, 1991). Reports of the possible effects of global climate change on our nation's farms and farmers have been mixed.

If climate change is caused only by an increased concentration of carbon dioxide (CO_2) in the atmosphere (not by increased levels of ozone, methane or CFCs), plants may benefit. In controlled situations, plants grow more quickly in the presence of higher CO_2 concentrations (Hillel and Rosenzweig, 1989). This is because CO_2 is the basic ingredient needed for photosynthesis, the process by which plants produce food (carbohydrates) and oxygen. When the concentration of CO_2 in the air of a laboratory plant chamber increases, so does the rate of photosynthesis. The same results are theoretically expected from increased CO_2 concentrations in an open wheat field. Another positive result of climate change may be a longer period of time between the first and last frosts in some areas of the United States. This could lengthen the growing season and allow for some areas to plant more than one crop per year, or to grow more hearty crops.

Negative effects of global climate change have also been considered. While warmer temperatures in some areas may lead to longer growing seasons, they may also lead some crops to mature too quickly if temperatures are too warm. As temperatures shift, many crops may become unsuccessful in their present locations. Transforming large numbers of farms within a widely settled country like the United States could be difficult. For example, the deep fertile soils of the Midwest are not found in other parts of the country at this time in geologic history. Cities and towns may be in the way of the new ideal farming sites. And if farms were unable to move, the need for irrigation and the competition for water could intensify. Coastal agriculture would also suffer if temperatures increase and result in a global sea level rise. Farms could be flooded, drainage could become too difficult to manage and salt water intrusion into ground water would increase.

Other countries may suffer more than the U.S. if climate zones shift. If we were to experience global warming that moved America's Corn Belt from middle America to the northern states, the country as a whole would still maintain its ability to grow corn. But smaller countries may not be able to adjust. Their livelihoods and natural resources may shift right out of the country. Agriculture in countries such as Bangladesh would be especially impacted if sea levels rise, because of their poor drainage systems.

While most projections about global climate change are stated in terms of annual average changes in temperature, it is important to look at climate variability and extremes when discussing agriculture. For example, as the number of days per year with temperatures over 90 degrees Fahrenheit increases, the yields of wheat crops decrease. And with higher daily maximum temperatures, corn crops produce lower yields (Hillel and Rosenzweig, 1989). Crops are very sensitive to changes in temperature throughout the year and from year to year. If one year is hot and dry while the next is cool and damp, it will be difficult to select the proper crops each year that would best suit the annual variations. Crops are also sensitive to extreme heat and cold. Just one extremely cold day can kill an entire crop.

Overall, doubling the level of CO_2 in the atmosphere (predicted to occur between 2030 and 2050 if human activities that add to greenhouse gases remain unchanged) would likely lead to less variable temperatures from year to year, but more variable precipitation (Rind, 1988). Increases in temperature would increase evaporation rates thus increasing precipitation but not uniformly across time or regions. Worldwide temperatures would be less variable; high latitude areas near the poles would warm more than equatorial areas since melting ice would reduce the pockets of cold air that currently cause temperature fluctuations throughout the year and across regions. The increased amount of precipitation would distribute in unpredictable patterns if projected wind patterns also shift as a

4.13 Agriculture (con't.)

result of overall temperature changes. The result could be more frequent droughts as well as floods. A report prepared for the Environmental Protection Agency (Smith and Tirpak, 1988) stated global warming in the United States would not threaten the U.S. food supply, but may:

1. increase yields of corn, soybeans and wheat in northern latitudes where warmer conditions may result in a longer growing season, and decrease yields of the same crops in middle latitudes where higher temperatures may decrease crop lifecycles;
2. increase yields of corn, soybeans and wheat since increased levels of CO_2 may increase plant growth;
3. result in a northward shift in cultivated land, and cause significant impacts on regional economies and dislocations of agriculture;
4. shift rainfall patterns, which may expand the need for irrigation and, therefore, increase the competition for regional water supplies and increase surface and groundwater pollution;
5. change the ranges and populations of agricultural pests; and
6. result in sea level rises and the flooding of coastal agricultural lands.

While global climate change may have positive effects on agriculture in some instances, it may also have devastating effects in others. Although the U.S. food supply may not suffer overall, the possible effects on local economies and foreign countries may be very serious.

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4.14 Global Change and Biological Diversity

Global change and biological diversity are inextricably tied. Michael Soule, in the forward to *Global Warming and Biological Diversity* (Peters and Lovejoy, 1992) titles his frontispiece "The Wrong Time for Climate Change." Soule sees the loss of biological diversity and integrity moving at a rapid pace and now it is potentially being further impacted by climatic warming. In the face of human dominated change, supported by such efficient technology, environmental systems are strained.

A world relatively uninfluenced by human natural systems could more readily adapt to climate changes. For example, today's grasslands are only small remnants of their original expanse, often isolated from other remnants. Plant and animal communities are physically isolated from potential migration routes or new refuges. In the face of potential climate change total communities and their diversity may be lost due to this isolation, loss of migration routes and the potential rapidity of climate-induced changes.

As atmospheric carbon dioxide (CO_2) continues to increase (30 percent-plus increase in the last 200 years) the likelihood of major consequences of worldwide impacts on biological resources increases. In turn the destruction of biomass through slash and burn practices, primarily in the tropics, also contributes to atmospheric CO_2 loading.

Persons wishing to explore the relationship between global change and biological diversity in depth are directed to Peters and Lovejoy's 1992 edited volume, *Global Warming and Biological Diversity*, which serves as both a primer and a status report on applicable research prior to 1992. Each chapter in the book provides reference lists to guide further reading.

Although many of the projections for global warming and subsequent global change are being debated, certain predictions have some level of agreement. In 1983 the National Research Council in "Changing Climate" predicated 3°C ± 1.5°C; in 1990 the Intergovernment Panel on Climate Change forecasted a 1°C change by 2025 and 3°C change by the end of the twenty-first century.

Schneider (1989) points out that warming will be fast, perhaps as much as 50 times faster than in the past. With the changes will come a rapid increase in fires, hurricanes and droughts. The secondary effects may have greater impact on biological resources than does the warming, per se.

Though the exact nature of ecological impacts are only at the modeling phase some specific responses have been identified. Peters and Lovejoy (1992) offer 10 edited chapters on general ecological and physiological responses to global warming. A variety of points are made by various authors in that section. For example, sugar maple, beech, yellow poplar and hemlock are predicted to die out in their southeastern U.S. range and establish a range much further to the north. Within 30 years the balsam-fir dominated softwood forest in Michigan is predicted to shift to a eastern hardwood forest, further endangering the Kirkland's warbler. Thermal stress is discussed as a factor that would more than likely limit animals' new ranges and would impact on fertility and fetal survival. Murphy and Weiss (1992) project a 23 percent loss of butterfly species in the mountain ranges of the Great Basin in the western United States.

Spread of tropical diseases from South and Central America can be expected. Pests that will impact the forest resources are also expected to become more prevalent. Migrating birds, with clearly synchronized patterns of movement to coincide with available food sources, are projected to be negatively impacted by climatic changes. This impact on already declining populations of migrating neotropical birds could have a devastating effect on both the birds and their associated food webs.

Issues of melting polar ice, sea level rise and changes in fluctuation of river systems all will impact marine species (i.e., bleaching and drowning of coral) and severely alter estuarian habitats. Based on arguments presented by the various authors in Peters and Lovejoy (1992) diversity as we know it is in danger.

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4.14 Biological Diversity (con't.)

Global change, in addition to a variety of other resource issues viewed as germane to protecting biological diversity, creates a cummulative effect. These effects, if the present estimates of global warming continue, will manifest themselves in highly altered ecological systems. For areas such as national parks and other protected areas their very reason for being will be threatened.

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4.15 Policy Choices

What can be done in light of the predictions of human-induced, rapid climate change? How can we plan for such a possibility and mitigate uncertain change? Even though the immediacy, and in fact the reality, of such global changes can not be proven beyond the shadow of a doubt, the possibilities of such devastating occurrences cannot be ignored. If governments decide to take action, there are two positions they may take.

First, some argue that we, as a thinking technological society, have the capabilities to mitigate the predicted consequences of global change enough to maintain an environment in which humans can survive before such changes ever arise. Mitigation is a widely used tool for enviornmental protection. For example, in order to mitigate the problem of erosion from construction near the banks of rivers or streams, some local laws require that builders place riprap close to the water's edges. These efforts on the behalf of the builder help to minimize the negative effects of construction on the local rate of erosion. The purpose of mitigation is to intervene on a possibly negative situation before it occurs in order to offset or slow its occurrence.

In the framework of global change, mitigating options would include attempts to reduce the amount of greenhouse gases being emitted into the air, as well as those that would "offset" the effects of global change by removing greenhouse gases from the air, blocking some of the sun's rays from reaching the Earth, or changing the amount of sunlight reflected by the Earth's surface (*Policy Implications of Greenhouse Warming*, 1991). While taking steps to reduce the possible effects of global change may lead to the avoidance of insurmountable problems in the future, such steps are costly in the present and may be found to be unnecessary if current predictions of global change are exaggerated.

If it is decided that efforts to mitigate the effects of global warming should be undertaken, there are several mitigating options that may be considered. Emissions may be reduced through managing industrial energy, building and managing efficient transportation systems, reforestation, capping gas which escapes from landfills, as well as many other emission reducing actions. Beyond the variety of actions that can be undertaken to reduce or eliminate greenhouse gas emissions, such mitigation techniques can be implemented through different types of policy. They can be put into effect by using regulations such as quotas or specifications for equipment or incentives such as subsidies and taxes (which can be thought of as reverse subsidies) (*Policy Implications of Greenhouse Warming*, 1991).

Some people have even proposed that "geoengineering" options be exercised in order to reduce the effects of global change. Such options are those that could possibly be devised and engineered by humans in order to reduce the effects of global change. Examples are blocking sunlight from the Earth with large space mirrors or dust that is purposely placed into the atmosphere, and stimulating microscopic organisms in the oceans to absorb CO_2 with iron (*Policy Implications of Greenhouse Warming*, 1991). These types of interventions, however, are still highly suspect.

The second main option may be to adapt to global change. Governments can help people and other life on Earth adapt to changes that will occur as climate changes. We have seen people survive in environments from the Galapagos Islands at the equator to the North Pole. Humans have great capacities to adapt to climate changes. But humans cannot survive alone. What about other species that humans and other species rely on? We witness species thriving in both Death Valley and Glacier Bay. But those species are highly specialized for life in such extreme conditions; they have adapted over time to these conditions. Research to develop drought resistant crops or discover means by which life can exist under rapidly changing conditions could increase the success of attempts to adapt to global warming.

Along with basic policies of mitigation or adaptation, research of the greenhouse effect needs to continue worldwide. None of the problems associated with global change will be caused by, or can be remedied by, one nation. Global efforts are needed to intervene in global change.

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4.16 Chronology of Global Climate Change

Global-scale climate changes occur very gradually over long periods of time. Scientists have documented the gradual fluctuations by identifying changes in soil layers and rocks, and in gas bubbles trapped in glacial ice.

However, there is increasing evidence that human activities are accelerating this natural phenomenon. Over the years, humans have changed rivers, seas, forests and soils, expanded the amount of land covered by cities, highways and farms, and increased the amount of gases discharged into the atmosphere.

Some recent studies reveal a slow rise in the average earthly temperature over the last 100-plus years. Now, scientists are challenged to determine whether this climate change is actually occurring, how much of this change is natural, and to what extent human activities are contributing to and accelerating these changes.

The following provides a historical perspective of events leading to the world's current awareness of global climate change:

Early 1800s The Industrial Revolution begins in Great Britain, spreading throughout the developed world. Fossil fuels like peat, coal, and later, oil used to power industry. Air pollution, especially in industrialized area, is drastically increased.

1863 John Tyndall, British scientist, describes how water vapor in the atmosphere helps to keep the world warm.

1896 Svante Arrenius, a Swedish chemist, warns that carbon dioxide (CO_2) released to the atmosphere from burning coal for industrial power is likely to make the world warmer.

1930 An American engineer, Thomas Midgley, proposes using new chlorofluorocarbons (CFCs) instead of ammonia for cooling refrigerators.

1957 International Geophysical Year. Regular monitoring of atmospheric CO_2 begins in Hawaii and Antarctica.

1970s Climatologists with high-speed computers begin projecting warming of three degrees to nine degrees by the end of the 21st century, based on carbon dioxide emissions.

1985 Scientists from 19 countries agree with a study crediting other trace gases, including CFCs, with adding as much to the greenhouse effect as CO_2.

1987 Global Climate Protection Act, PL 100-204, becomes law. Montreal Convention is held to consider how to limit atmospheric pollution by CFCs.

1987 *Our Common Future*, known as the Brundtland Report after its chairman, Gro Harlem Brundtland, publishes the findings of the World Commission on Environment and Development. While its conclusions do not please all environmental experts, it is a major information resource and rallying point.

1987–1988 Drought, fires and severe heat waves arouse public anxiety and conjecture that they are first signs of global warming.

1988 Intergovernmental Program on Climate Change (IPCC) is convened in Geneva for the first time.

1989 Seventy-one nations, meeting in The Netherlands, agree to a Declaration on Atmospheric Pollution and Climatic Change.

1990 At the fourth meeting of the IPCC in Sweden, the United States joins 73 other nations in agreeing that humans' activities are causing the Earth's atmosphere to heat up.

1991 President Bush hosts a climate change treaty negotiating session in Chantilly, VA, in February.

1991 United Nations environment conferences are held in Nairobi, Kenya, in June and in Geneva, Switzerland, in September.

1992 In June, the world focuses its attention on the "Earth Summit," the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil. Treaties and agreements which are negotiated, and signed by leaders of many countries, may lead to more sensitive use of the planet's diminishing resources.

1993 President Clinton and Vice President Gore release the Climate Change Action Plan.

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4.17 The Global Warming Panic

By Warren T. Brookes

On Nov. 7 the U.S. and Japan shocked environmentalists around the world by refusing to sign a draft resolution at a Netherlands international conference on global climate change calling for the "stabilization" of emissions of carbon dioxide (CO_2) and other "greenhouse gases" by the year 2000. Instead, they made the conference drop all reference to a specific year, and to a specific CO_2 reduction target. The Bush Administration view was set forth by D. Allan Bromley, the presidential science adviser, in testimony to Senator Albert Gore's subcommittee on Science, Technology & Space. "My belief is that we should not move forward on major programs until we have a reasonable understanding of the scientific and economic consequences of those programs."

President Bush was immediately savaged by environmentalists, and by politicians like Senator Gore (D–Tenn.) The Bush viewpoint does not sit too well with most of the media, either. Last January *Time* published a cover story on environmental catastrophes, declaring that greenhouse gases could create a climatic calamity. The *New York Times* weighed in a month ago with a story about how melting polar ice would flood the nations that can least afford to defend themselves, Third World countries like Bangladesh and India. Or perhaps you have seen the ads for Stephen Schneider's *Global Warming*, accompanied by a blurb from Senator Tim Wirth (D–Colo.). In his book this well-known climatologist paints a future of seas surging across the land, famine on an epidemic scale and ecosystem collapse.

Is the earth really on the verge of environmental collapse? Should wrenching changes be made in the world's industry to contain CO_2 buildup? Or could we be witnessing the 1990s version of earlier scares: nuclear winter, cancer-causing cranberries and $100 oil? The calamitarians always have something to worry us about. Consider this: In his 1976 book, *The Genesis Strategy*, Schneider lent support to the then popular view that we could be in for another ice age, "perhaps one akin to the Little Ice Age of 1500-1850. Climatic variability, which is the bane of reliable food production, can be expected to increase along with the cooling."

At the very moment Bromley was testifying to Gore's subcommittee, MIT's prestigious *Technology Review* was reporting on the publication of an exhaustive new study of worldwide ocean temperatures since 1850 by MIT climatologists Reginald Newell, Jane Hsiung and Wu Zhongxiang. Its most striking conclusion: "There appears to have been little or no global warming over the past century." In fact, the average ocean temperature in the torrid 1980s was only an eighth of a centigrade degree (a quarter of a Fahrenheit degree) higher than the average of the 1860s. Ocean temperature is now virtually the same as it was in the 1940s. Since two-thirds of the buildup of CO_2 has taken place since 1940, the MIT data blow all of the global warming forecasts into a cocked hat. President Bush wisely told reporters "You can't take a policy and drive it to the extreme and say to every country around the world, 'You aren't going to grow at all.' "

That is the central issue of the global warming debate, and it explains why the U.S. and Japanese position was supported by some 30 other developing nations which see that just as Marxism is giving way to markets, the political "greens" seem determined to put the world economy back into the red, using the greenhouse effect to stop unfettered market-based economic expansion.

In simplest terms, the earth's atmosphere does operate as a greenhouse. In addition to oxygen, nitrogen and water vapor, the atmosphere contains several gases that trap radiated heat, including methane and CO_2. Carbon dioxide is essential not only to warmth but to vegetation. It is also essential to life in another way: Without its heat-containing effect the planet would freeze, like the atmospherically naked moon.

Throughout most of human history that atmospheric blanket has held global temperatures at an average of about 60 degrees F., plus or minus 5 degrees F. During most of human history, the CO_2 concentration in that blanket has, until this century, hovered around 270 parts per million, although in earlier geologic epochs it reached as high as 20,000.

Over the last 100 years the CO_2 concentration has risen from 270 to today's level of 350. The culprit: man. Most of the greenhouse gas increase is the result of fossil fuel consumption. Add to that the rise in other man-generated trace gases—methane, nitrogen oxides and chlorofluorocarbons—and total greenhouse gases are now at 410 ppm. In other words, because of the combined effect of these gases, we have already gone over halfway to a doubling of CO_2. Even so, there has been less than half a degree of warming in the last 100 years.

What do the environmental pessimists make of all this? The earliest versions of their computer "general circulation models" predicted that the earth would warm up by anywhere from 3 to 5 degrees centigrade, or 5 to 9 degrees Fahrenheit, by the year 2050. The most extreme scenarios warn of coastal flooding (from melting ice caps) and rising inland droughts. However, as the level of sophistication of the models has risen, these forecast effects have been steadily reduced to a new range of 1.5 to 2.5 degrees centigrade.

One major exception to this declining rate of doom is the model run by James Hansen of the National Aeronautics & Space Administration, who shocked a congressional hearing in

June 1988 during the middle of a scorching near-nationwide drought, by saying he was "99% confident" the greenhouse effect is now here.

Even though the vast majority of the climatological community was outraged by Hansen's unproven assertions, environmental advocate Stephen Schneider notes in *Global Warming*, "Journalists loved it. Environmentalists were ecstatic. Jim appeared on a dozen or more national television news programs. . . . "

By the end of 1988, with Hansen and Schneider's enthusiastic support, global warming was deeply embedded in the public consciousness. Now over 60% of the public is convinced it will worsen, even as the evidence of that alleged trend is under increasingly sharp and solid scientific attack.

On the contrary, that attack has been used as a premise for even more immediate action. As one TV anchorman argued, "Even if we aren't sure it's true, shouldn't we take precautions and act now as if it were?"

Unfortunately, "taking such precautions" could well spell the end of the American dream for us and the world. Once CO_2 is in the atmosphere, we can't easily remove it. Since most of the forecast rise in the gas is a function of simple economic and population growth in the Third World, there is no realistic economic way to prevent a CO_2 doubling without slashing growth and risking a revolt of the have-not nations against the haves. The Washington, D.C.-based Center for Strategic & International Studies points out that, even though the U.S. is now the largest carbon fuel user, it's the developing countries that will quadruple their energy consumption by 2025. "By the middle of the next century, they will account for the bulk of the greenhouse gases emitted into the atmosphere, even if they succeed in doubling energy efficiency."

The Environmental Protection Agency finds that just to stabilize U.S. CO_2 emissions at present levels would force 30% taxes on oil and coal, while to meet environmentalists' demands for a 20% reduction in U.S. CO_2 emissions would require a tax of $25 per barrel on oil, and $200 a ton on coal, effectively doubling U.S. energy costs.

Unfortunately, the popular media don't seem to care. In May the national press erupted in a two-day firestorm when Hansen told Senator Gore's subcommittee that the Office of Management & Budget had censored his florid global warming testimony by adding the modest caveat, "These changes should be viewed as estimates from evolving computer models and not as reliable predictions."

Yet, at the moment of that testimony, 61 of the world's top climatologists, gathered for a five-day workshop in Amherst, Mass., were largely agreeing with OMB. *Science* magazine reported that most of the attendees were pleasantly surprised by OMB's efforts to control Hansen: "I can't say I agree with censorship, but it seems OMB has better people than I thought. I'd have to agree with their angle," said Rick Katz of the National Center for Atmospheric Research, one of the leading modelers.

Conference leader Michael Schlesinger, another top modeler (University of Illinois), agreed: "[Hansen's] statements have given people the feeling the greenhouse effect has been detected with certitude. Our current understanding does not support that. Confidence in its detection is now down near zero."

That conclusion was buttressed by one of the deans of U.S. climatology, Reid Bryson, a founder of the Institute for Environmental Studies at the University of Wisconsin, who said in July: "The very clear statements that have been made [by Hansen] that the greenhouse warming is here already and that the globe will be 4 degrees [centigrade] warmer in 50 years cannot be accepted."

On Dec 24, 1988, Hansen received an unwelcome Christmas present in the form of a new research paper by one of the world's most universally respected climatologists, Thomas Karl, and two of his colleagues at the National Oceanographic & Atmospheric Administration, Kirby Hanson and George Maul. Their review of the best climate record in the world—that of the 48 contiguous United States—concluded: "There is no statistically significant evidence of an overall increase in annual temperature or change in annual precipitation for the contiguous U.S. 1895-1987." Look at the chart on pages 96-97. As Karl says in an interview, "If there is a greenhouse warming effect, you can't find it in the U.S. records."

That news alone should have cooled off the global warming movement. But the environmentalists accepted Hansen's dismissal of the paper as "not significant" because the data covered only 1.5% of the earth's surface, not nearly enough to identify major trends.

But MIT meteorologist Richard Lindzen says that Hansen's rebuttal is out of line. He points out that because of the law of large numbers—the fact that a large enough sample is likely to give an accurate picture of a larger population—"the absence of any trend in the record of the contiguous U.S. leads to the suspicion that all the trends in the global record may be spurious."

The major reason for this is that when you fully subject global temperature records (as Karl did the U.S. records) to adjustment for the effects of urbanization (cities are heat islands that artificially inflate temperature records), the global warming trend since 1880 has been only a third of a degree centigrade, and over the Northern Hemisphere land masses, no trend at all.

Here's another fact, noted by Hugh Ellsaesser of Lawrence Livermore Laboratories, that should trouble the calamity theorists: Most of the past century's warming trend took place by 1938, well before the rise in CO_2 concentration. From 1938 to 1970 temperatures plunged so sharply a new ice age was widely forecast. Furthermore, the warming trend since 1976 has been just the opposite of that forecast by the greenhouse model, with *cooling* in both the northern Pacific and North Atlantic.

In fact, the Northern Hemisphere shows no net change over the last 55 years, during which CO_2 concentration rose from approximately 300 to 350 ppm and other thermally active trace gases were in their steepest growth phases.

In spite of this clear lack of correlated warming evidence, one of the leading climate models now predicts that a 1% annual rise in CO_2 should, over 30 years, produce a 0.7-degree centigrade warming. But when Patrick Michaels of the University of Virginia applied that formula to the period from 1950 to 1988, when greenhouse

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gases rose 1.2% per year, he found a tiny 0.2-degree warming in land temperatures, where the model would have predicted 1.3 degrees. When a model cannot come within 500% of explaining the past, it is useless as a predictor of anything.

As Reid Bryson concludes in a 1988 paper, "A statement of what the climate is going to be in the year A.D. 2050 is a 63-year forecast. Do the models have a demonstrated capability of making a 63-year forecast? No. A 6.3-year forecast? No. Have they successfully simulated the climatic variation of the past century and a half? No. They are marvels of mathematics and computer science, but rather crude imitators of reality."

The major weakness of the models is their assumption that the CO_2 buildup is the significant climate variable, and should *ceteris paribus* (all other things being equal) generate warming. But, as it turns out, the *ceteris* are decidedly not *paribus*.

One of those variables is cloud cover, which is at least 100 times more powerful in affecting temperatures than greenhouse gases and is infinitely variable. Yet, because cloud cover has been documented only for a decade or so (by weather satellites), the models have little to go on. Until recently, the modelers assumed that warmth gave rise to the kind of clouds that trap heat, contributing still further to warming, in a vicious cycle. But in June 1988, V. Ramanathan of the University of Chicago and a team of scientists at NASA concluded from preliminary satellite data that "clouds appear to cool earth's climate," possibly offsetting the atmospheric greenhouse effect.

The supreme irony is that this "cooling effect," most pronounced in the Northern Hemisphere, coincides with the paths of coal-burning emission plumes with their high concentration of sulfur dioxide. That confirms a long-held thesis that sulfur dioxide creates "cool clouds." Of course, it is very upsetting to an environmentalist to discover that a pollutant has a beneficial side effect.

Sulfur dioxide emissions not only acidify rain, they combine with water vapor to form what are known as "aerosols," which have the effect of brightening clouds and making them reflect more heat away from the earth. Wisconsin's Reid Bryson described this effect as early as 20 years ago. Bryson's thesis was scorned at the time. But last June, Thomas Wigley, one of England's top climatologists and a global warming enthusiast, conceded in a paper in *Nature* magazine that sulfur dioxide cooling "is sufficiently large that the effects may have significantly offset the temperature changes that resulted from the greenhouse effect."

Michaels says this could also explain in part why U.S. daytime highs (when brighter clouds have the most cooling effect) have actually declined substantially in the last 50 years, even as the nighttime lows have risen. "This should make you wonder," says Michaels, "why Hansen [and others] have only perturbed their models with CO_2, and not with SO_2 as well. If you only perturb the model with CO_2, it will predict the greenhouse warming effect. If you only perturb it with SO_2, you get an ice age."

Hugh Ellsaesser says the main reason the models have been so completely wrong in "predicting" the past is that they completely ignore the countervailing, thermostatic effects of the hydrological cycle of evaporation and condensation. Two-thirds of the predicted global warming is due not directly to CO_2's radiative power but to an indirect effect: Carbon dioxide warming supposedly causes a threefold amplification of water vapor surface evaporation into the atmospheric blanket.

But Ellsaesser says in the warmer, tropical latitudes, where the temperature change from sea-level upward is most rapid, evaporation has the opposite effect. There, water vapor rises by deep convection in fast-rising towers. This in turn leads to more rapid condensation and precipitation, which then causes a drying and thinning of the upper atmosphere in a process called subsidence. "In the lower latitudes, a rise in CO_2 emissions will produce a 3-to-1 rise in greenhouse blanket *thinning* due to condensation. That's exactly the opposite of what the models predict," he says.

An eminent British scientist, Sir James Lovelock, says this hydrological process "is comparable in magnitude with that of the carbon dioxide greenhouse, but in opposition to it." National Oceanographic scientist Thomas Karl agrees: "We will eventu-

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ally discover how naive we have been in not considering CO_2's effects on cloud cover and convection. As CO_2 speeds up the hydrological cycle, more convection creates more clouds and more cooling. So, the greenhouse effect could turn out to be minimal, or even benign."

MIT's Richard Lindzen thinks that correcting for deep convection alone could lower the global warming estimates by a factor of six. As a result, he says, "It is very unlikely that we will see more than a few tenths of a degree centigrade from this cause [CO_2] over the next century."

In the face of such mounting evidence, U.S. businesses may stop worrying about devastating legislative enactments. That could be a mistake. As Nobel economist James Buchanan argues, what drives Washington policymaking is not economic or scientific realities but "public choice," the pursuit of power and funding.

The public choice potential of global warming is immense. Under a global warming scenario, the EPA would become the most powerful government agency on earth, involved in massive levels of economic, social, scientific and political spending and interference, on a par with the old Energy Department. Don't forget the energy crisis: During the 1970s, a great many less-than-honest scientists confidently predicted the world was about to run out of fossil fuels, and that by 1985, we'd be paying $100 a barrel for oil, or more. We wasted billions on energy subsidies.

Senator Albert Gore is evidence of this public choice phenomenon. He seems determined to run his next presidential campaign at least in part on climate change, saving Mother Earth. Every year, at least one-sixth of the U.S. is classified by the government's Palmer Index as being in drought. Even though that index overstates the case, Gore could be looking at some very big political states—maybe California or Texas or Iowa—where his message will resonate with farmers and business. All he has to do is wait for a warm spell, and capitalize on what mathematicians call noise in the statistics.

Patrick Michaels explains: "We know that the Pacific Ocean current known as El Niño tends to warm and cool in two-year cycles. Just as its warming cycle produced the 1987-88 droughts, in 1989 it cooled sharply, making the U.S. much cooler and wetter than Hansen had forecast, and that is likely to happen in 1990, again. But that means that 1991 and 1992 should be warmer and drier than usual as the El Niño current warms. It won't matter that this has nothing to do with global warming, the media will perceive it that way, and people will tend to believe it."

Bernard Cohen, a physicist at the University of Pittsburgh, warns, in a 1984 book: "Our government's science and technology policy is now guided by uninformed and emotion-driven public opinion rather than by sound scientific advice. Unless solutions can be found to this problem, the U.S. will enter the 21st century declining in wealth, power and influence. . . . The coming debacle is not due to the problems the environmentalists describe, but to the policies they advocate."

"Global warming" may well prove Cohen right. ■

4.18 Slowing Global Warming

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SLOWING GLOBAL WARMING

By CHRISTOPHER FLAVIN

Is climate change a Chicken Little proposition, as some observers say? We don't think so, and you won't either after reading this.

Global warming promises to be one of the central environmental issues of the '90s. After a decade of scientific concern but popular neglect, the '80s ended with a growing political and scientific consensus that the world can no longer afford to procrastinate about this issue. Plans call for the drafting of an international climate treaty in 1990, and for its formal adoption at a global environmental summit in 1992.

This action can hardly come too soon. Changes to the earth's atmosphere are by nature global and—for all practical purposes—irreversible, not only in our lifetimes but in those of our children and grandchildren as well. Lending urgency to the problem is the fact that the chemical composition of the earth's atmosphere is already quite different than it was just a century and a half ago. We have already committed ourselves to more climate change than many societies will be able to cope with.

Christopher Flavin is vice president for research at Worldwatch Institute, a nonprofit research group devoted to analyzing global environmental issues. This article is excerpted from a chapter of Worldwatch's prestigious book, State of the World 1990. *The book may be ordered from Worldwatch Institute, 1776 Massachusetts Ave. NW, Washington, DC 20036. Hardcover, $18.95; paperback, $9.95*

Nitrogen and oxygen are still the main constituents of the atmosphere, but several more complex gases are building steadily: carbon dioxide (CO_2) is up 25 percent, nitrous oxide 19 percent, and methane 100 percent. Chlorofluorocarbons (CFCs), a class of synthetic chemicals not normally found in the atmosphere, have added further to this blanket of gases that allow sunlight in but trap the resulting heat.

Global average temperatures are now about 0.6 degrees Celsius warmer than they were 100 years ago. No conclusive proof links this recent heating to the greenhouse effect, but circumstantial evidence has convinced many scientists that this is the cause. Of more concern, however, is the much faster warming that is predicted by a half-dozen computer models—reaching an increase of 2.5 to 5.5 degrees Celsius late in the next century. The difference between the warming of the past century and that expected in the decades ahead is like that between a mild day in April and a late-summer scorcher.

Although climate change is a young science, many aspects of which are uncertain, this is no excuse for delay. Societies invest in many programs, such as defense, to protect against an uncertain but potentially disastrous threat. Similarly, investing in strategies to slow global warming is a sort of insurance policy—against catastrophes that have far greater odds of occurring than do most events for which we buy insurance. And many of these programs are economical investments in their own right, cutting energy bills and air pollution as well as helping to restore the carbon balance.

Coping effectively with global warming will force societies to move rapidly into uncharted terrain, reversing powerful trends that have dominated the industrial age. This challenge cannot be met without a strong commitment by both individual consumers and governments. In terms of the earth's carbon balance, the unprecedented policy changes that have now become urgent include a new commitment to greater energy efficiency and renewable energy sources, a "carbon tax" on fossil fuels, a reversal of deforestation in tropical countries, and the rapid elimination of CFCs.

The Global Carbon Budget

The element carbon has become one of the largest waste products of modern industrial civilization. During 1988, some 5.66 billion tons were produced by the combustion of fossil

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fuels—more than a ton for each human being. Another one to two billion tons were released by the felling and burning of forests, mainly in tropical areas. Each ton of carbon emitted into the air results in 3.7 tons of carbon dioxide, the seemingly innocuous gas that is now one of the principal threats to humanity's future.

Global carbon emissions have grown rapidly during the postwar period. It took 10 years for them to go from two billion to three billion tons, but just six more years to get up to four billion. This trend has of course been fueled by other exponential growth rates—namely of population and economic output, which translated into ever-greater use of fossil fuels. Increases in oil use have been particularly rapid, but during the '80s the use of coal and gas has also swelled.

The past four decades of growth can be broken into three distinct periods. (See Figure 1.) From 1950 to 1973, the annual increase in carbon emissions was a remarkably steady 4.5 percent;

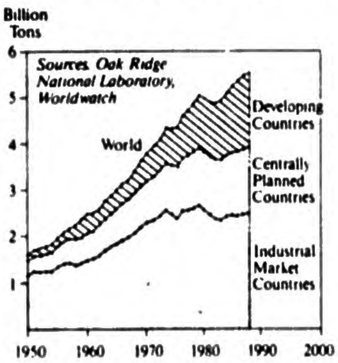

Figure 2-1. Carbon Emissions from Fossil Fuels, 1950-88

Table 1. Carbon Emissions from Fossil Fuels, Selected Countries, 1960 and 1987

Country	Carbon 1960	Carbon 1987	Carbon per Dollar GNP 1960	Carbon per Dollar GNP 1987	Carbon per Capita 1960	Carbon per Capita 1987
	(million tons)		(grams)		(tons)	
United States	791	1,224	420	276	4.38	5.03
Canada	52	110	373	247	2.89	4.24
Australia	24	65	334	320	2.33	4.00
Soviet Union	396	1,035	416	436	1.85	3.68
Saudi Arabia	1	45	41	565	0.18	3.60
Poland	55	128	470	492	1.86	3.38
West Germany	149	182	410	223	2.68	2.98
United Kingdom	161	156	430	224	3.05	2.73
Japan	64	251	219	156	0.69	2.12
Italy	30	102	118	147	0.60	1.78
France	75	95	290	133	1.64	1.70
South Korea	3	44	274	374	0.14	1.14
Mexico	15	80	446	609	0.39	0.96
China	215	594	—	2,024	0.33	0.56
Egypt	4	21	688	801	0.17	0.41
Brazil	13	53	228	170	0.17	0.38
India	33	151	388	655	0.08	0.19
Indonesia	6	28	337	403	0.06	0.16
Nigeria	1	9	78	359	0.02	0.09
Zaire	1	1	—	183	0.04	0.03
World	2,547	5,599	411	327	0.82	1.08

SOURCE Worldwatch Institute, based on Gregg Marland et al., *Estimates of CO_2 Emissions from Fossil Fuel Burning and Cement Manufacturing, Based on the United Nations Energy Statistics and the U.S. Bureau of Mines Cement Manufacturing Data* (Oak Ridge, Tenn. Oak Ridge National Laboratory (ORNL), 1989), Gregg Marland, ORNL, private communication, July 6, 1989, Economic Research Service, *World Population by Country and Region, 1950-86, and Projections to 2050* (Washington, D.C. U.S. Department of Agriculture, 1988), U.S. Central Intelligence Agency, *Handbook of Economic Statistics, 1988* (Washington, D.C. 1988), World Bank *World Development Report 1989* (New York Oxford University Press, 1989)

from 1973 to 1983, emissions gyrated wildly but on average increased at a yearly rate of just 1.0 percent; since then, more rapid growth has resumed, at an average rate of 2.8 percent a year. In 1988, carbon emissions went up 3.7 percent, the largest annual increase in almost a decade.

If expansion had continued at the pre-1973 rate, annual emissions today would be almost three billion tons higher. Of course, the slowdown was not the result of actions to protect the atmosphere. It stemmed from the effects of the two oil crises, energy-policy changes in some countries, and global economic problems that have hit developing countries severely.

More than one-third of the drop in the carbon-emissions growth rate since 1973 can be traced to the declining energy intensity of many countries, although a large disparity in per-capita carbon emissions still exists even among industrial market countries (see Table 1). The impact of improved energy efficiency would have been even greater except for the fact that the efficiency revolution largely bypassed other parts of the world. Rising use of renewable energy and nuclear power played a significant but smaller role since 1973, offsetting some 500 million tons of annual emissions.

In Eastern Europe and the Soviet Union, where most industries and in-

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dividuals are shielded from market incentives, energy intensities have remained essentially unchanged, and efficiency in most sectors is only about half that in Western Europe. Thus, although Soviet per-capita economic output (measured in purchasing power) is only two-thirds that of Western Europe, per-capita carbon emissions are almost twice as high. Though economic restructuring is intended to improve energy efficiency and thus reduce carbon emissions, a Soviet society with automobiles and larger houses could push carbon emissions beyond the current level.

The Third World currently burns fossil fuels at far lower rates than the industrial world. With many people continuing to live in poverty in the countryside, fossil fuels are often too expensive or simply unavailable. In many of these countries, a sizable portion of energy needs is met through the combustion of wood, straw, and other biomass fuels, which despite their importance are not generally counted in energy statistics. Yet burning these fuels also emits carbon, and when they are not replaced by new trees or other plants, the atmosphere receives an additional burden.

Many developing countries are adding far more carbon to the atmosphere through deforestation than through fossil-fuel combustion. Brazil, for example, contributes some 336 million tons of carbon each year through deforestation, over six times as much as through burning fossil fuels (see Table 2). Combining these two sources makes Brazil the fourth largest carbon emitter in the world. Deforestation also pushes Indonesia and Colombia into the top 10 global emitters.

Although considerable uncertainty remains about the precise rate of deforestation, strong circumstantial evidence indicates it is accelerating. Tropical countries report ever more rapid losses of forests, and satellite reconnaissance confirms this. As with fossil-fuel use, this suggests a challenge ahead. It is one thing to accomplish a goal from a standing start. It is quite another to turn around an ongoing and powerful trend.

The U.S. Environmental Protection Agency has estimated that to stabilize atmospheric concentrations of CO_2 at the current level, carbon emissions must be cut by 50 to 80 percent, taking them back to the level of the '50s. Policymakers meeting in Toronto in June 1988 offered a short-term goal: cutting them by 20 percent by 2005.

Even a 20-percent cut in carbon emissions would mark a dramatic shift in direction and require wholesale changes in energy policy and land-use patterns around the world. Such goals, though feasible, will force policymakers to consider familiar issues in a dramatically different context. In the past, international emissions of carbon were left to the marketplace. But markets by nature ignore environmental costs. Continuing with business as usual will result in a rapid undermining of the habitability of the planet during the next 20 to 30 years.

Any realistic strategy must start with the fact that one-fourth of the world's population accounts for nearly 70 percent of the fossil-fuel-based carbon emissions. This wealthy, energy-intensive quarter has an obvious responsibility to lead in the search for solutions. But the level of carbon emissions in developing countries remains an extraordinarily difficult issue. It is a simple fact of science that the planet will never be able to support a population of eight billion people generating carbon emissions at the rate, say, of Western Europe today.

The implied growth to just more than 16 billion tons of carbon emissions per year during the next few decades would result in a concentration of CO_2 that is perhaps three times the preindustrial level—well above even the doomsday scenarios developed by climate modelers. But even continuing along the current path would not leave the world in much better shape. At the recent annual growth rate of about three percent, carbon emissions in the year 2010 would reach nearly twice the current level, and by 2025 would be three times where we are today. And since other greenhouse gases are rising in concentration as

Table 2. Estimated Carbon Emissions from Deforestation and Fossil Fuels in Selected Countries

Country	Deforestation, 1980	Fossil Fuels, 1987	Total
	(million tons)		
Brazil	336	53	389
Indonesia	192	28	220
Colombia	123	14	137
Thailand	95	16	111
Côte d'Ivoire	101	1	102
Laos	85	<1	85
Nigeria	60	9	69
Philippines	57	10	67
Malaysia	50	11	61
Burma	51	2	53
Others[1]	509	181	690
Total[1]	1,659	325	1,984

[1]65 countries.

SOURCES R A Houghton et al, "The Flux of Carbon from Terrestrial Ecosystems to the Atmosphere in 1980 Due to Changes in Land Uses Geographic Distribution of the Global Flux," *Tellus*, February-April 1987, Gregg Marland, Oak Ridge National Laboratory, private communication, July 6, 1989

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Significantly more economical than fossil-fuel substitutes are a number of the emerging renewable options, including wind, wood, geothermal, and solar thermal, with carbon-avoidance costs as low as $107 per ton. Moreover, all these costs are falling. The cheapest way to reduce carbon emissions, however, is energy efficiency—enormously abundant and costing a maximum of $19 per ton of avoided carbon. Indeed, many efficiency investments are less expensive than operating existing coal-fired power plants, meaning that the cost of avoided carbon emissions is zero.

Other Greenhouse Strategies

As noted earlier, two important components of efforts to slow global warming are the reversal of deforestation backed by a commitment to replant trees, especially in the Third World, and the elimination of chlorofluorocarbons. The first of these relies on using forests and agricultural lands as a carbon sink.

Several analysts have attempted to estimate the carbon-fixing potential of various kinds of forest, and to design appropriate tree-planting programs. In *State of the World 1989* we considered the likely contribution of 130 million hectares (321 million acres) of tropical forest—an area twice the size of France. Trees covering that much territory, planted around the world, could meet the fuelwood and timber needs of the Third World and restore degraded lands. At the same time, they would sequester about 5.5 tons of carbon per hectare. Such a "carbon bank" would absorb 660 million tons of carbon each year until the trees reach maturity in about three decades. This is more than a third of the amount currently thought to be emitted each year by deforestation, and a little under 10 percent of total net carbon emissions.

Slowing deforestation requires that tropical countries end financial incentives for land speculators and settlers to move into virgin forests and for loggers to export hardwoods. Governments and international aid agencies also need to work actively to support sustainable development projects such as agroforestry and woodlots that allow people to make a living from forests that are left standing rather than cutting them down.

Remarkably, in a 1989 policy paper on global warming, the World Bank concluded that "the economics of vigorously pursuing (reforestation) are probably not favorable at this time." This statement ignores the impact of the current rate of deforestation and the potential leverage of the international community in easing the pace of destruction. Stopping deforestation within their own borders is by far the largest contribution that many developing countries can make to global climate stabilization, as well as to their own economic futures.

Countries in temperate regions can also help restore the earth's carbon balance by planting trees. Surveys show that Europe and Japan are the only parts of the world currently increasing their total forested area. Even in Canada and the United States, forests are shrinking, largely due to the spread of land-intensive suburban and commercial development. And in both North America and the Soviet Union, the clearcutting of virgin forests not only continues but is subsidized by governments. Relatively minor policy changes could convert North American, central Asian, and Australian forests into net carbon absorbers. The prime minister of Australia has taken the lead in such efforts with his recent announcement of a program to plant one billion trees by the end of this decade. *(And President Bush deftly played one-upsmanship in his January State of the Union speech, calling for the planting of a billion trees* a year *in the U S.—Ed)*

A major step in this direction would be to convert large areas of marginal crop and grazing lands to trees, which stabilizes soils at the same time as it increases the rate of carbon fixing. Trees planted, for example, on the 13 million hectares (32 million acres) of erodible cropland set aside in the United States since 1986 under the Conservation Reserve Program would absorb 65 million tons of carbon annually for the first few decades. This would lower U.S. net carbon emissions by about five percent, a major step. Once the new trees reach maturity, in 20 to 30 years, and cease to absorb carbon, they could be harvested on a sustainable basis for use as fuel to replace oil or coal, further lowering carbon emissions.

A number of cities have already decided that the local benefits of tree planting are so great that they will not wait for national governments or the international community to adopt new measures. The American Forestry Association launched a program in late 1988 called Global ReLeaf,® which aims to encourage U.S. communities to plant 100 million trees by 1992. This project was spurred by concern over global warming and the desire of individuals to make a contribution. (One hundred million growing trees would sequester an estimated five million tons of carbon annually.)

Global ReLeaf® also recognizes that tree planting will improve the urban environment itself, moderating summer heat and improving aesthetics. The mayor of Los Angeles announced in February 1989 that the city hopes to plant between two million and five million trees by 1994, and in September the mayor of Houston, Texas, set forth a plan to plant two million trees by 2000. Other cities are expected to join in.

The real challenge facing these programs is maintaining the trees once they are in the ground. In the past, trees put in during crash campaigns, such as in China, have been plagued by high mortality rates. This can be prevented only by careful nurturing of the saplings. If such difficulties can be overcome, tree planting will make a small but important contribution to climate stabilization. Newly planted trees have an even larger educational and symbolic value, enlisting individuals and their communities in the fight to slow global warming.

A National and Global Policy Agenda

This past year has been marked by a flurry of proposals to deal with

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well, the amount of warming would be well above that projected from carbon dioxide alone.

A frighteningly large gap looms between projected growth rates in carbon emissions and the level that atmospheric scientists believe is necessary to maintain a climate that can meet human needs. World leaders meeting at the Hague environmental summit in March 1989 and the Paris economic summit in July 1989 agreed on a need to cut carbon emissions. But no one has begun to wrestle with the crucial equity issues this need raises.

How much of a burden should the United States, as a wealthy and energy-intensive country, have to bear? And what about Japan, which is frugal in its consumption of fossil fuels but is one of the few nations with capital surpluses? Should the use of fossil fuels be constrained in developing countries or should most of their effort be devoted to reversing deforestation? And what of the Soviet Union, which is embarking on an economic program that could boost energy consumption even higher than it already is?

A growing world population and the associated demand for energy, land, and other resources will also have an impact on carbon emissions. In countries such as Kenya and the Philippines, a three-percent annual growth rate of emissions is just enough to stay even with population, implying static per-capita carbon emissions. Successful efforts to slow population increases would allow such nations to cut emissions more easily. Indeed, unless Third World population growth does slow drastically, it is hard to imagine any global program of carbon reductions that is both sufficient and equitable.

Alternatives to Fossil Fuels

Fossil fuels today provide 78 percent of our energy (oil provides 33 percent; coal 27 percent, and natural gas 18) But we have always known that the world must stop using them eventually since nonrenewable resources are by definition limited and will one day run out. Now the specter of global warming requires us to phase out fossil fuels during the early part of the 21st century, long before reserves are depleted. Not only do they contain carbon, but the extraction and use of fossil fuels contribute a significant share of the emissions of two other greenhouse gases—methane and nitrous oxide.

Although it is important that the transition away from fossil fuels begin in the near future, the process will extend over a period of decades. Many new technologies will have to be developed, and even then, installing replacement sources will take time.

Fossil-fuel alternatives include several renewable energy sources poised to develop rapidly. Wind, geothermal, solar thermal, photovoltaic, and various biomass technologies are among the energy sources with potential to move strongly into the market during the '90s. And renewable energy technologies as a group have a big advantage over nuclear power as a means of reducing CO_2 emissions: they can be used not only to produce electricity but also to displace many other uses of fossil fuels, such as running autos.

Biomass sources such as wood, agricultural wastes, and garbage have great potential to fuel a sustainable energy system. Already, biomass supplies about 12 percent of world energy, a figure that reaches as high as 50 percent or more in some developing countries. Much of this use is not sustainable, however, and could even exacerbate global warming. In Brazil, for example, smelters fueled by wood from virgin forests emit more carbon dioxide than if they were fueled by coal. Yet with careful management and efficient conversion, these sources could play an important role in a sustainable world energy system.

Wood- and waste-fired power plants are now being built in many nations at costs competitive with those of fossil-fuel plants. They produce minimal air pollution, and as long as they use waste materials or wood from forests that are being replanted, they do not add to CO_2 buildup. Power plants that burn methane building up in landfills are particularly effective at slowing global warming, since they consume a gas with 25 times the greenhouse strength of carbon dioxide. A California study found that a kilowatt-hour of electricity produced this way removes methane equivalent to the carbon released by 10 kilowatt-hours generated by a coal-fired plant.

Among the transport fuels that yield substantially lower carbon emissions are alcohol fuels from biomass. Brazil has the world's largest alcohol-fuels program, with about 72 million barrels of ethanol derived from sugarcane annually. In 1988, this provided 62 percent of the country's automotive fuel. Although this huge program has helped reduce Brazil's dependence on imported oil, it has done so at the price of enormous government subsidies. The United States is the second largest producer of alcohol fuels—20 million barrels per year, derived mainly from corn. But this country is no model either, since its program is also subsidized and is based on a crop grown on prime land. Because fossil fuels are used in the production, U.S. ethanol yields only a 63-percent reduction in carbon emissions on an energy-unit basis.

To make biomass fuels a workable alternative, the world will have to turn to crops grown on marginal lands, to conversion of waste materials, and to the development of integrated cropping systems that allow the same land to produce as much food as at present, and to produce fuel as well.

As societies adopt the slowing of climate change as a guiding principle in selecting energy strategies, it is important that they seize alternatives that are both practical and economical. The relative cost of avoiding carbon emissions is one central consideration for policymakers to keep in mind. In many nations, coal-fired electricity is still the mainstay of the power system, so it makes sense to evaluate technologies that can displace the carbon emitted by this form of energy. Since the fuel and operating costs of a coal-fired power plant are about two cents per kilowatt-hour, and pollution costs about 1.5 cents per kilowatt-hour, anything above 3.5 cents can be attributed to "carbon avoidance."

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have to be cast aside, so that countries can act in concert as never before.

This seemed to be recognized by leaders of the seven largest industrial democracies, meeting in Paris for their annual summit in July 1989. Environmental proposals occupied one-third of the resulting communique. On global warming, the leaders said, "We strongly advocate common efforts to limit emissions of carbon dioxide and other greenhouse gases, which threaten to induce climate change."

After the rhetoric, however, come complex and difficult negotiations. That process began in November 1988, when representatives of 30 countries met in Geneva under the auspices of the United Nations Environment Programme (UNEP) and the World Meteorological Organization. Following a pattern established in arms talks, these nations have formed an Intergovernmental Panel on Climate Change that will meet periodically to forge an agreement.

The first step is the establishment of ambitious but practical goals for the reduction of carbon emissions, particularly in those countries that currently use fossil fuels most heavily. Any plan that reduces carbon emissions is also likely to help cut back on two other greenhouse gases, nitrous oxide and methane. Only by reducing carbon emissions at least 10 percent in the next decade can the world get on course to at least halve emissions by mid-century.

Table 4. Costs of Avoiding Carbon Emissions Associated with Alternatives to Fossil Fuels, 1989

Fossil Fuel Alternative	Generating Cost[1]	Carbon Reduction	Estimated Pollution Cost	Carbon Avoidance Cost[2]
	(¢/kwh)	(percent)	(¢/kwh)	($/ton)
Improving Energy Efficiency	2.0–4.0	100	0.0	<0–19[3]
Wind power	6.4	100	0.0	107
Geothermal energy	5.8	99	1.0	123
Wood power	6.3	100	1.0	141
Steam-injected gas turbine	4.8–6.3	61	0.5	109–200
Solar thermal (with gas)	7.9	84	0.5	216
Nuclear power	12.5	86	5.0	535
Combined cycle coal	5.4	10	1.0	814
Photovoltaics	28.4	100	0.0	921

[1]Levelized cost over the life of the plant, assuming current construction costs, and a range of natural gas prices. [2]Compared with existing coal-fired power plant. [3]Some energy efficiency improvements cost less than operating a coal plant, so avoiding carbon emissions is actually free.

SOURCE. Worldwatch Institute estimates.

In an effort to balance practicality and equity against the urgency of the problem, we have formulated a set of reduction targets based on today's per-capita carbon emissions levels (see Table 5). Countries such as the United States and the Soviet Union that currently produce carbon dioxide at a high rate would be required to reduce emissions by about 35 percent in the next 10 years, while nations such as India or Kenya could continue to increase emissions. Those with carbon emissions between these two extremes, such as Italy and Japan, would have to reduce them less rapidly.

The goals are designed to gradually narrow the disparities that now exist among national emissions levels. They are also practical, calling for a realizable 12-percent cut in global emissions by the year 2000 (see Table 6). Under them, projected emissions of 6.4 billion tons are 38 percent below what they will be if the world continues on its current path. Although a 12-percent reduction would not by itself stabilize the climate, it would put the world on a course toward stabilization of global CO_2 concentrations by mid-

Table 5. Proposed Emission Goals, Sample Countries

Current Carbon Emissions Level	Suggested Emissions Targets	Sample Countries
(tons/person)	(percent/year)	
<0.5	+3.0	Kenya, India, Niger
0.5–1.0	+1.5	China, Nigeria, Philippines
1.0–1.5	0	Indonesia, Mexico, South Korea
1.5–2.0	−0.5	Italy, France, New Zealand
2.0–2.5	−1.0	Japan, Thailand, Peru
2.5–3.0	−2.0	Great Britain, West Germany, Brazil
>3.0	−3.0	Australia, United States, Soviet Union, Colombia, Côte D'Ivoire

SOURCE. Worldwatch Institute, based on Gregg Marland et al., *Estimates of CO_2 Emissions from Fossil Fuel Burning and Cement Manufacturing* (Oak Ridge, Tenn. Oak Ridge National Laboratory, 1989). R.A. Houghton et al., "The Flux of Carbon from Terrestrial Ecosystems to the Atmosphere in 1980 Due to Changes in Land Use. Geographic Distribution of the Global Flux," *Tellus*, February-April 1987

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global warming. According to one U.S. count, 130 bills were introduced in 22 state legislatures during the first half of 1989. Major proposals are also being debated in national parliaments (see Table 3). And in some areas, city government and private groups are getting into the act as well. Rarely has a new policy issue taken hold so quickly.

In the United States, two comprehensive global warming bills were first introduced in Congress in late 1988. They proposed a national goal of cutting carbon emissions 20 percent over the next 10 years and included programs to implement national least-cost planning, improve automobile fuel economy, develop renewable energy sources, plant trees, and assist developing countries in slowing population growth and deforestation. In the ensuing months, however, the bills ran into the opposition of entrenched industries, and key elements of the legislation failed to move forward.

The picture in Europe is more encouraging. The public is strongly concerned about climate change, is willing to pay to avoid it, and is electing politicians who are ready to act. The Netherlands, Norway, and Sweden are considering plans to freeze or cut national CO_2 emissions. In Sweden, one oil-fired power project has already been put on hold pending evaluation of its greenhouse impact. The United Kingdom and West Germany report similar sentiments and are reviewing their energy policies. A special West German commission is likely soon to suggest major policy initiatives, but already the opposition Social Democratic Party has called for higher energy taxes, new efficiency incentives, and a sweeping overhaul of utility laws. An inexorable environmental bandwagon may next push the European Parliament, with its dominant coalition of pro-environment parties, to take up related proposals.

Other parts of the world are moving much more slowly on a greenhouse policy agenda. Brazil, China, Japan, and the Soviet Union have done little beyond supporting more research and strong rhetoric. Canada, which has played a leading role in international discussions, failed to reach agreement on a 20-percent-reduction goal at an August 1989 meeting of provincial energy ministers. Some small countries however, have actively supported new policy initiatives on global warming. These include nations like the Maldives and Malta that believe they may be big losers as the climate changes.

National goals to limit emissions of the four main greenhouse gases--carbon dioxide, CFCs, methane, and nitrous oxide—are among the most important features of any meaningful global warming strategy. But beyond establishing goals, it is important that credible policies be put in place to achieve them, including giving relevant government agencies responsibility to implement useful measures.

It is encouraging that so many governments have begun to mobilize to slow global warming, but an international agreement to stabilize the climate is still needed. Indeed, global warming presents an unprecedented challenge to the global community, forcing everyone from prime ministers to the general public to understand that we inhabit a single planet and share responsibility for its health. National differences and old rivalries will

Table 3. Climate Policies, Enacted and Proposed, November 1989

Nation or State	Policy	Status
The Netherlands	*Proposal to freeze CO_2 emissions by 2000 and increase spending on efficiency*	*Parliament debating proposals; government considering four-year, 8-percent reduction in CO_2 emissions*
Norway	*Plan to stabilize CO_2 emissions by 2000, then reduce emissions*	*White paper approved by parliament in June 1989*
Sweden	*Plan to freeze CO_2 emissions at current levels; tax CO_2 emissions*	*Parliament approved emissions freeze, 1988; tax planned by 1991*
United Kingdom	*Considering control of methane leakage, improved energy efficiency*	*House of Commons Energy Committee recommendations*
United States	*Comprehensive legislation to cut carbon emissions 20 percent*	*Several bills pending in U.S. Congress*
California	*Comprehensive policy being developed*	*Government report to be submitted June 1990*
Oregon	*Law requiring 20 percent reduction in greenhouse gases by 2005*	*Enacted July 1989*
Vermont	*Order to decrease greenhouse gas emissions, re-evaluate state energy policy*	*Proposal announced by Governor September 1989*
West Germany	*Comprehensive policy under discussion*	*Parliament Commission formulating proposals; report due mid-1990*

SOURCE: Worldwatch Institute, based on various sources

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century (see Figure 2).

What would a climate-change agreement for the '90s look like? The first element would be a commitment to stabilize atmospheric concentrations of greenhouse gases by the middle of the 21st century, reducing net carbon emissions to a maximum of two billion tons per year. With a projected world population of eight billion, this would imply a per-capita rate of carbon emissions close to India's today, or one-eighth the European level. To get to this point, the world needs to end the production of CFCs and to cut global carbon emissions by 10 to 20 percent over the next decade, adopting country-specific targets based on the per-capita figures described earlier. Within a year of the agreement's signing, each country would submit a plan to achieve the goals, and then issue progress reports every two years. Negotiators, meanwhile, would consider the adoption of stricter goals to begin in 2000.

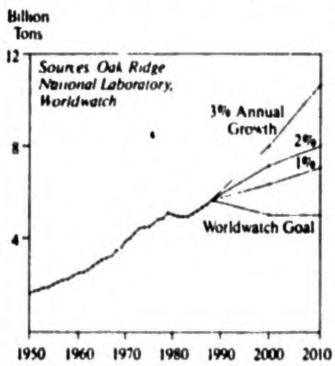

Figure 2-2. Carbon Emissions from Fossil Fuels, 1950–88, With Alternative Projections to 2010

To accomplish these goals, UNEP would need to become a more powerful agency, given the tasks of coordinating research and of reviewing and assisting with national climate strategies. Verification is essential to a credible agreement. But today UNEP has a minimal budget and is mainly chartered to coordinate the work of larger U.N. organizations. Recognizing this weakness, the leaders of 17 countries, including France, Japan, and West Germany, met in the Netherlands in March 1989. The resulting Hague Declaration called for the development within the United Nations of a strong new institutional authority with powers to carry out the provisions of a global warming agreement.

As the scientific evidence mounts, the time has arrived for a global warming agreement—comprehensive, detailed, and prescriptive. Only a rapid turnaround in carbon-emissions trends can begin to get the world on the path to a stable climate. Wholesale changes in energy, land use, and population policies are implied. Unless such action is taken in the next few years, however, the '90s will become a lost decade for the world's atmosphere, relegating the next generation to a world less able to meet growing human needs. No other environmental problem has such an exponential and cumulative dimension to it, a fact that argues persuasively for the immediate adoption of strong policies.

The benefits of such an effort extend well beyond stabilization of the climate. Economies would be strengthened, new industries created, air pollution reduced, and forests preserved for their economic and recreational benefits. For humanity as a whole, it would be another step in the evolution of society, demonstrating the ability to work cooperatively as a world community. It would be an auspicious beginning to the new millennium. **AF**

Table 6. Global Carbon Emissions, 1988, and Goals for 2000 and 2010

Area	1988 Carbon	1988 Per Capita	2000 Carbon	2000 Per Capita	2010 Carbon	2010 Per Capita
	(million tons)	*(tons)*	*(million tons)*	*(tons)*	*(million tons)*	*(tons)*
North America	1,379	5.07	897	3.03	662	2.13
Soviet Union and Eastern Europe	1,428	3.55	964	2.23	872	1.91
Oceania	336	2.27	284	1.79	270	1.65
Latin America	910	2.09	803	1.46	764	1.18
Western Europe	774	2.03	699	1.79	664	1.67
Middle East	187	1.14	187	.83	217	0.74
Africa	534	.86	646	73	749	0.64
Centrally Planned Asia	774	66	932	.69	1,082	0.73
Far East Asia	833	.55	998	.52	1,158	0.52
World[1]	7,319	1.42	6,435	1.03	6,438	0.93

[1]The sums of the columns by region do not equal the world total due to U.N. reporting irregularities.

SOURCE Worldwatch Institute estimates, based on Gregg Marland et al., *Estimates of CO_2 Emissions from Fossil Fuel Burning and Cement Manufacturing* (Oak Ridge, Tenn. Oak Ridge National Laboratory, 1989), Economic Research Service, U.S. Department of Agriculture, *World Population by Country and Region* (Washington, D.C. 1988), R.A. Houghton et al. "The Flux of Carbon from Terrestrial Ecosystems to the Atmosphere in 1980 Due to Changes in Land Use. Geographic Distribution of the Global Flux, *Tellus*, February-April 1987, and British Petroleum, *BP Statistical Review of World Energy* (London 1989)

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4.19 A Character Sketch of Greenhouse Effect

by Dr. David Rind

The Greenhouse Effect has caught the imagination of the general populace in the last decade. What's more, the respected, generally conservative scientific establishment has become associated with relatively dire predictions of future climate changes the Greenhouse Effect may cause.

But how much do we actually know about the Greenhouse Effect? Can we really establish how much the climate will change, and when? Perhaps by separating the "hard" science—that which can be verified and is considered well-understood—from scientific theory or estimates, we *can* investigate the likelihood of near-term climate changes that have been projected. The series of questions which follow will help us explore what we currently know, or think we know, about the Greenhouse Effect.

Question: Do we really understand the "Greenhouse Effect"?

The "Greenhouse Effect" is the name for the physical process whereby energy from the sun passes through the atmosphere relatively freely, while heat radiating from the earth is partially blocked or absorbed by particular gases in the atmosphere. Because the sun is warmer than the earth, its energy is radiated at a higher frequency which is not absorbed well by gases such as carbon dioxide (CO_2) or water vapor. In contrast, these triatomic gases (gases with three atoms per molecule) are effective absorbers of the lower-frequency energy radiated by the earth. Since the gases responsible for this selective absorption make up only about one percent of the atmosphere, they are known as "trace" gases. In general, we can calculate very accurately the energy absorbed by different gases, although there are some uncertainties, and when the concentration of a gas changes, we know how much more energy is being absorbed. This additional absorption by itself warms the planet: for example, doubling the concentration of CO_2 in the atmosphere would eventually lead to a global air temperature increase of 1.2° Centigrade (C)—about 2.2° Fahrenheit (F)—if there were no other changes in the climate system.

However, what we do not know is exactly how the rest of the system will react. The current numerical computer models of the earth's climate predict that the warming due to the increase in CO_2 will lead to more evaporation of water vapor from the ocean. Water vapor itself is a "greenhouse" gas, so as its concentration increases in the atmosphere, the planet will warm even further. With rising temperatures there will be less snow and ice to reflect energy from the sun back to space (snow and ice are very good reflectors). This promotes further warming because more of the sun's heat is retained in the earth.

These are examples of "positive feedbacks" in which the system responds to a warming climate with changes which amplify the warming even further. Both of these system responses are very likely to occur, although we cannot be sure of the magnitude of the changes. The models also predict cloud cover changes that will provide even more warming, but clouds are not modeled in a very sophisticated way because they are not well understood. Thus, the likely impact of cloud cover changes is quite uncertain.

The net result of these different processes in the various models is the tripling of the warming caused by the doubled CO_2 levels alone, producing a total warming of about 4° C (or 7° F) for the global, annual average. Yet it is only the initial Greenhouse Effect due to increased CO_2 or increases in other trace gases, which we know with great confidence.

Question: Can we use the temperatures on other planets to determine what the climate system feedback will be on earth?

The atmospheres of nearby planets validate the general concept of the greenhouse *theory*, especially in a qualitative sense, but they cannot tell us what the magnitude of the changes on earth will be. Venus, with its massive atmosphere composed essentially of CO_2, has a surface air temperature close to 500° warmer than would be expected without a Greenhouse Effect. Mars, with a very thin atmosphere and thus little atmospheric capacity to absorb radiation, has an observed temperature close to the expected. The earth, with intermediate amounts of greenhouse gases in its atmosphere, is about 30° C (54° F) warmer than it would be otherwise. The differences among the planets are very large, and cannot really be used to estimate sensitivity to relatively small changes in greenhouse gas levels. Furthermore, as noted above, the big uncertainty lies in the magnitude of the climate system response (or feedbacks). The most important feedbacks involve the reaction or processes related to water, and the other planets have no free-standing water.

Are greenhouse gases increasing?

Since the establishment of an atmospheric monitoring system in 1958, we have observed the concentration of CO_2 growing systematically. During the past 28 years, CO_2 values in our atmosphere have increased from 315 parts per million (ppm) to 350 ppm. These values are especially significant since air bubbles trapped within the ice in Greenland and Antarctica have been used to measure what CO_2

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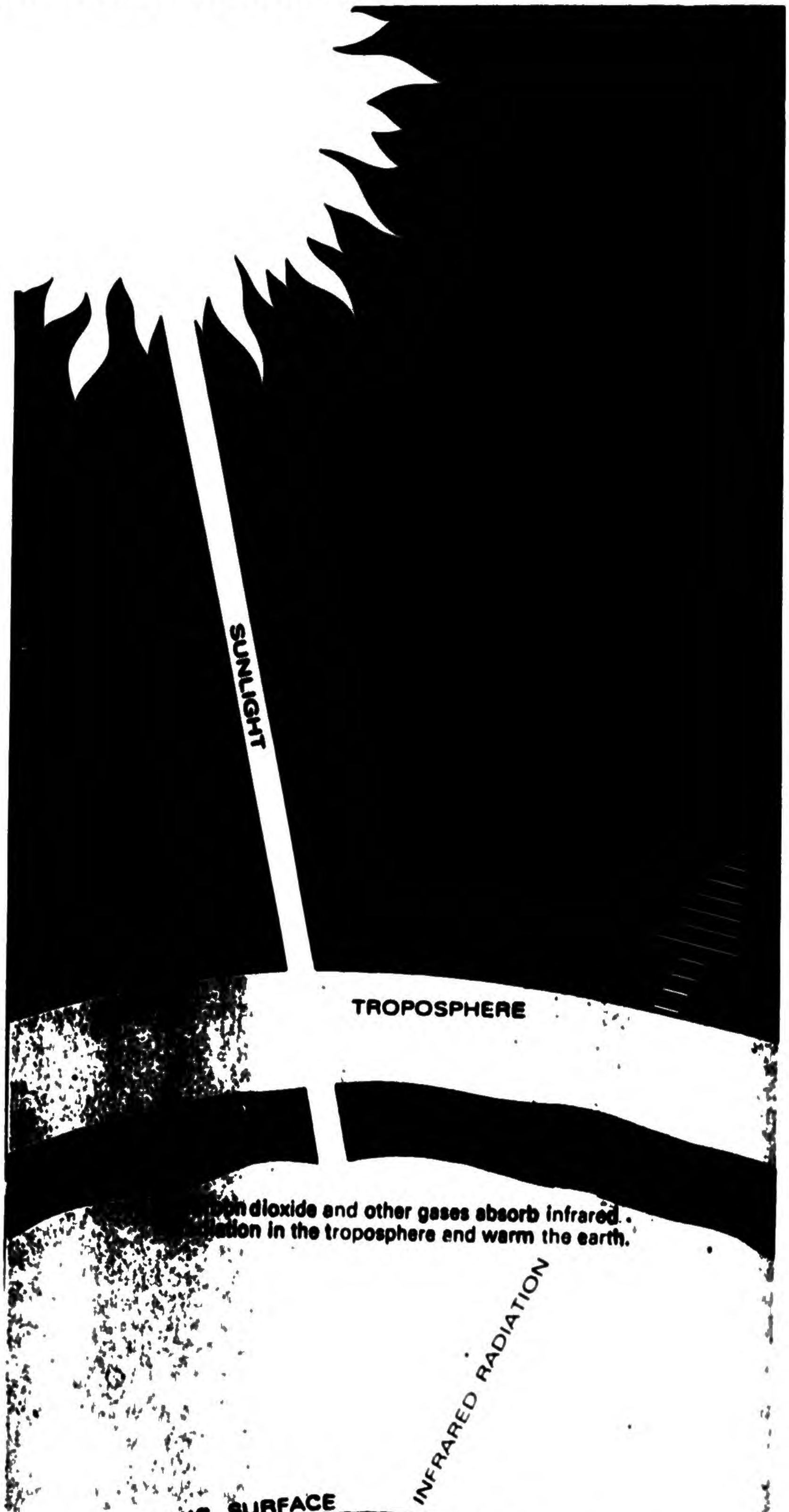

concentrations were like over the past several hundred thousand years. During that time, up to just prior to the industrial revolution, CO_2 levels had not exceeded 280 ppm (and thus were well below current values). The rising CO_2 concentrations are believed to be associated with the widespread use of fossil fuels such as gas and oil and by the denuding of the world's tropical and other forests, a process which lowers the earth's ability to use trees as a CO_2 absorbent.

Chlorofluorocarbons (CFCs), better known for their impact on atmospheric ozone levels, are artificially generated gases that also have the capacity to contribute to the Greenhouse Effect, and which are known to be increasing. They have no natural sources and probably did not exist in the atmosphere prior to the last few decades. Recent measurements indicate that other contributing greenhouse gases, such as methane and nitrous oxide, are also increasing; however, since we are not sure of the reason for their increase, we have less confidence in their long-term trends.

Question: Is the temperature record of the past century consistent with the increase of gases which contribute to the Greenhouse Effect?

It is estimated that the average surface air temperature has increased globally by about 0.6° C (or 1° F) in the past century, but there is some uncertainty as to how accurately the change can be estimated because there were far fewer temperature recording stations 100 years ago. Large portions of the globe were poorly sampled, especially in the Southern Hemisphere. Even today, full global coverage is not available.

The record, such as it is, does not indicate a continuous worldwide

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warming. There was apparently a cooling period in the Northern Hemisphere from the 1940s into the early 1970s. This is inconsistent with the concept of greenhouse warming, but it may be due to other climate disturbances such as variations in the solar energy constant, or a change in the amount of volcanic discharge into the atmosphere, or it may simply represent internal variability within the system.

The overall warming for the past century is the right order of magnitude for the expected Greenhouse Effect. However, given the uncertainties about the actual temperature change, the climate feedback factor, the actual amount of CO_2 in the atmosphere in 1880, and the rate at which oceans absorb heat (which slows down the atmospheric warming), we cannot be more precise in determining what the expected warming would have been. Similarly, we cannot use the record to establish what the climate-feedback factor really is.

Despite these qualifications, one aspect of the temperature record clearly stands out: during the past century, the four warmest years, globally, were all during the 1980s; this does not include 1988, which appears as if it will be the warmest year of all. This has occurred despite the eruption of the El Chicon volcano, putting additional dust into the air, and a decrease in the sun's energy output, both of which should have had a cooling effect. While modern temperature records may be contaminated to some extent by heat island effects which create warm areas in cities, the rapid rise of temperature during the 1980s is consistent with computer model projections. This suggests that the anticipated Greenhouse Effect changes may actually be appearing at this time.

Question: Are current computer models adequate to allow us to forecast climate change?

Numerical models (called general circulation models) which simulate the known workings of the earth's climate system are used to calculate its response to increases in trace gases. The four models in current use all estimate that the doubled CO_2 climate will have a global average temperature some 4° C (7° F) warmer than today. They are thus all calculating similar climate feedback factors. However, even though many climate processes are handled similarly in the different models, their unanimity does not guarantee accuracy. For example, the treatment of cloud cover in all the models represents a major uncertainty. The models also differ to some extent as to the seasonal and latitudinal distributions of the calculated warming. It is thought unlikely that the models could be wrong by more than a factor of two, but this cannot be proven.

In addition, a climate change forecast should indicate when the warming would be expected to be evident, but only one model, the Goddard Institute of Space Studies (GISS) model, has been used to calculate the temperature increase over the next 50 years in response to a gradual change in greenhouse gas concentrations. Its results indicate substantial warming in the next decade. This calculation is affected to some extent by uncertainties in how much heat the oceans will absorb and the true climate feedback factor. Nonetheless, by providing an estimate of how much warming should be observed in the relatively near future, the model does give us a chance to test the accuracy of its projections.

Question: How "dire" is the forecast of coming climate change?

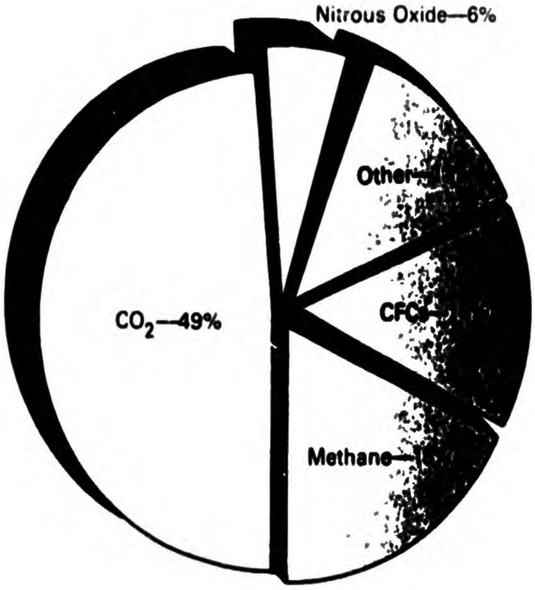
It is estimated that the ice age climate was some 4° C colder than today's. At that time (some 18,000 years ago), ice covered the area now occupied by New York City. Considering that the doubled CO_2 climate is estimated to be warmer to the same degree that the ice ages were cooler, large changes in the climate system may well be expected if this comes to pass. The GISS model's forecast for the next 50 years gives changes of 2° C (3.6° F) by the year 2020, which would make the earth warmer than it is thought to have been at any point in historical time. Estimates for summer temperatures in the doubled CO_2 climate indicate that Washington, DC, which currently experiences 36 days of temperature above 90° F would routinely have 87 such days; Dallas would go from 19 days with temperatures above 100° F to 78 days.

Sea-level rise due to thermal expansion of the oceans would cause severe problems in many coastal cities, and this effect would be exacerbated if additional glacial melting occurred. Rainfall patterns would likely be substantially altered, posing the threat of large-scale disruptions of agricultural and economic productivity, and water shortages in some areas.

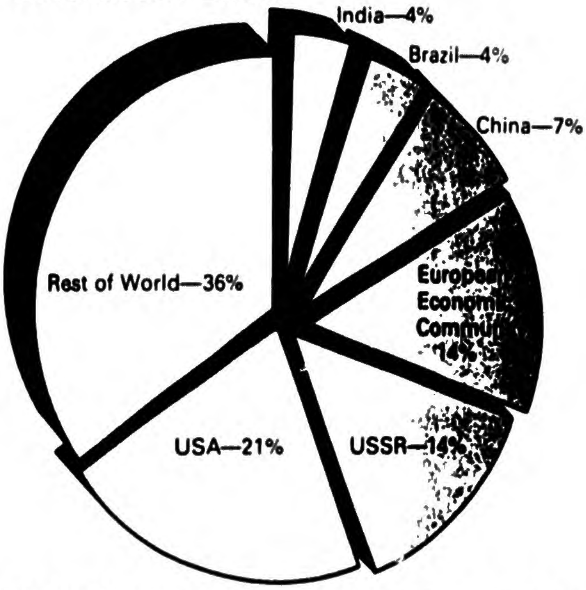
We may start experiencing the effects of a changing climate fairly soon. If we define a "hot" summer as the warmest one-third of the summers during the period 1950-1980, then, if the models are correct, during the 1990s we will experience "hot" summers twice as often, or two-thirds of the time. The summer of 1988 may be an all-too-tangible indication of how dire such changes in summertime climate can be.

4.19 A Character Sketch...(con't.)

Manmade Contributions to the Greenhouse Effect



Regional Contributions to the Greenhouse Effect



(The top chart represents the estimated increase in the Greenhouse Effect due to manmade emissions of Greenhouse gases in the 1980s. The chart is adapted from work by Dr. James Hansen and his associates at the Goddard Institute for Space Studies. The bottom chart is based on EPA estimates of each region's contribution to manmade emissions of Greenhouse gases.)

Question: Is there any way to prevent these changes from occurring?

The climate is being altered by the release of greenhouse gases due to fossil fuel consumption and industrial processes, and by deforestation. These factors are inherent in our current civilization. It may be possible to limit specific trace gas increases (such as the CFCs) and slow down rates of increase of CO_2 through increased energy conservation. Our ability to manipulate the climate system deliberately, so as to offset the warming by some other process, is nonexistent. It is likely that the additional greenhouse gases which have been added to the atmosphere during the past 50 years have already built considerable warming into the system, which we have not yet experienced because of the slow warming response of the ocean.

The climate of the next century will very likely be substantially different from that to which we have become accustomed. Uncertainties in our knowledge of the true climate sensitivity prevent us from knowing exactly how different it will be. The consequences of the climate change that is currently being estimated would be enormous. With that in mind, it is worthwhile for us to factor climatic change into decision-making processes related to our future, even though there are many uncertainties that still exist in our understanding of what may actually happen. □

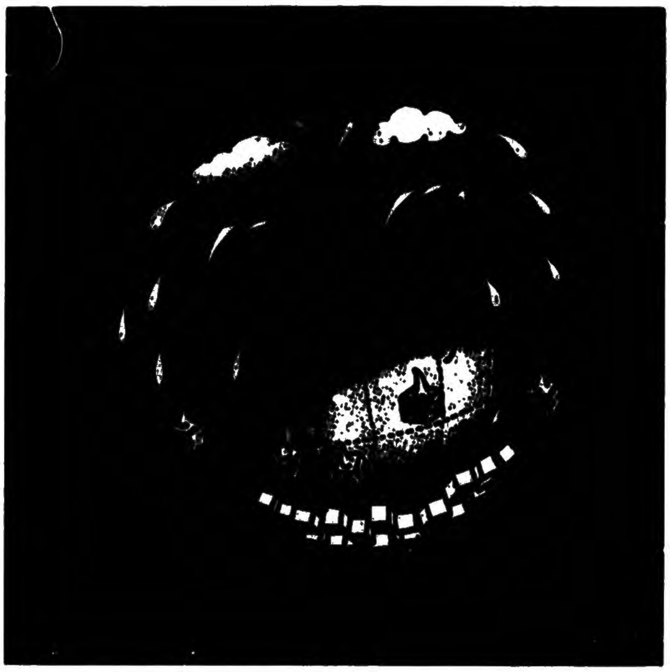
(Dr. Rind is an atmospheric scientist at the Institute for Space Studies, Goddard Space Flight Center, National Aeronautics and Space Administration, and an adjunct associate professor at Columbia University. He is a leading researcher on aspects of the greenhouse theory of atmospheric warming from certain gases.)

EPA Journal (Jan/Feb 1989)

4.20 The Greenhouse Question

Inside Stories | By Alston Chase

THE GREENHOUSE QUESTION



BOB CONGE

IT WAS TIME FOR SUNBLOCK AND SEERsucker. Last May, a United Nations panel of experts turned up the heat in the escalating debate over global warming. (Unless you live in an ice cave, you're familiar with the theoretical scenario: By burning rainforests and fossil fuels, humans are pumping too many "greenhouse gases," such as carbon dioxide, into the atmosphere; these gases trap the sun's heat—the "greenhouse effect"—causing worldwide temperatures to rise, with dreadful consequences.) This band of some 250 scholars, known as Working Group I of the Intergovernmental Panel on Climate Change, claimed to have found proof that the ultimate heat wave has begun. According to the *Washington Post*, the IPCC's report predicted that "worldwide temperatures will rise an unprecedented two degrees within 35 years and more than six degrees by the end of the next century.... Temperatures will be far greater than any experienced in the last 10,000 years."

Scary stuff—but the story was a canard: The report did not yet exist. It was still being written at the time and was not scheduled for publication until September. The dire predictions actually came from an executive summary of the report, distributed by IPCC staffers, which several participating scientists say distorted the panel's findings. As Hugh W. Ellsaesser, an atmospheric scientist at Lawrence Livermore National Laboratory, told me: "The summary wrongly implied greater certainty than was expressed in the draft report."

The world is in a sweat over global warming. But should it be?

The press and public, in short, had been flimflammed. Publication of the IPCC's conclusions before its study was completed—an action that the prestigious British scientific journal *Nature* called "seriously in error"—was a gambit to force policy decisions before predictions could be verified. And indeed, it prompted world leaders, members of Congress, and environmentalists to call for immediate action. Colorado Senator Timothy Wirth declared, "The jury is in on global warming." David R. Doniger of the Natural Resources Defense Council remarked, "It is getting harder and harder for our country to hide behind the veil of insufficient knowledge." Even Great Britain's ice-madam, Prime Minister Margaret Thatcher, concluded, "The problems do not lie in the future. They are here and now."

The IPCC release also sent a big chill through the Bush administration. The president had been under enormous pressure to stop talking about the weather and start doing something about it. Last November, at a 68-nation conference on the greenhouse effect held in Noordwijk, The Netherlands, the United States was criticized for its refusal to accept a Dutch proposal for curbing carbon dioxide emissions; in February, at a meeting of the IPCC, many environmentalists urged the United States to take immediate action to avert global warming; in April, at a meeting on global warming called by the White House, representatives from several countries

Fact Sheets

4.20 The Greenhouse Question (con't.)

chided the United States for failing to act.

Bush had been justifying the delay by insisting that more research was needed. Now that sounded like a lame excuse. In June, in an effort to slow the juggernaut unleashed by the IPCC, EPA Chief Administrator William K. Reilly continued to insist that global warming was not "understood with the degree of certainty that would warrant" taking action. The administration again resolved to wait until more research, both on the physics of global warming and on the costs of stopping it, is completed; this month it says it will present results of some of these studies—those regarding the economic impacts of alternative greenhouse policies—at the second annual World Climate Conference in Geneva. Given the pressures on Bush to do something, a decision to act may follow this meeting. The president has already agreed in principle to reduce production of carbon dioxide; only the amount of the reduction and the method for achieving it remain to be worked out. So a national global-warming policy is probably just around the corner.

But it will almost certainly be premature. Global warming is indeed a serious issue that must be studied carefully. It may be real, or it or may be the biggest scientific dead-end since the flat-earth theory. We simply do not know. And so in its hotheaded jump to conclusions about global warming, our civilization is revealing one of its greatest weaknesses: an inability to respond appropriately to environmental uncertainty.

"Probable nor'east to sou'west winds, varying to the southard and westard and eastard and points in between; high and low barometer, sweeping round from place to place, and probable areas of rain, snow, hail and drought, succeeded or preceded by earthquakes with thunder and lightning." Mark Twain's 1876 spoof of New England weather forecasting is uncannily applicable to today's global-warming rhetoric.

Richard E. Ayres, of the Natural Resources Defense Council, has said that global warming will have such "fundamentally devastating" effects on agriculture and natural resources that "the dangers to our economy, national security, and the stability of the world's economic and political systems cannot be overstated." Frederic D. Krupp, director of the Environmental Defense Fund, wrote in a recent mail solicitation that global warming "could raise average temperature to the point that breadbaskets turn into dustbowls and ocean levels rise to cause catastrophic flooding of coastal cities and lowlands." And last fall, the Worldwatch Institute, in its publication *Slowing Global Warming*, said that rising temperatures will "follow an exponential curve," leading to droughts and a "loss of 50–400 million lives."

According to most computer models that project global warming, it would happen like this: The ocean would act as a "heat sink," at first trapping excess heat and leading to a rise in ocean temperatures. Next, daytime temperatures in the temperate and polar zones would go up dramatically, melting ice caps and causing sea levels to rise. Worldwide temperatures would become more uniform, and winds, driven by heat differentials, would weaken. Northern temperate zones would become warmer and wetter; tropical areas, drier.

But these predictions are not coming true. Although greenhouse gas concentrations have increased the equivalent of a 50 percent rise in atmospheric carbon dioxide since 1880, most recent data suggest that the net rise in global temperatures has been zero. In January of last year, scientists from the National Oceanic and Atmospheric Administration reported finding no warming in the United States since 1895. Last fall, after an exhaustive study that traced worldwide ocean temperatures since 1850, a team of MIT climatologists concluded, "There appears to have been little or no global warming over the past century." Northern Hemisphere surface temperatures, they said, rose about one degree Fahrenheit between 1900 and 1940 but declined from 1940 to 1980—the period during which most greenhouse gases were added to the atmosphere. Since 1980, the earth has warmed a fraction of a degree, but this has occurred in nighttime temperatures, and entirely in equatorial waters—not in the daytime in temperate zones. Meanwhile, winds have increased, and the polar ice caps are

The apocalyptic predictions about warming ignore a host of uncertainties and contrary facts.

thickening.

The apocalyptic predictions also ignore a host of other contrary facts and uncertainties:

Natural temperature cycles. We still don't know, for example, what causes ice ages, or whether we are at the end of one ice age or the beginning of the next.

The carbon cycle. Until recently, most scientists assumed that 40 percent of atmospheric carbon dioxide was absorbed by the oceans. But a recent study conducted jointly by NOAA, NASA's Goddard Institute for Space Studies, and the Lamont-Doherty Geological Observatory has suggested that land masses are the major carbon dioxide sinks. Still, they don't know where the gas goes. "We've been overconfident," observes NOAA's Pieter P. Tans, "about our knowledge of the carbon cycle."

Timing. Last May, an analysis of ancient antarctic ice-cores reported in *International Geophysical Year* revealed that global warming did follow periods of increased carbon dioxide concentrations—but not until 3,000 to 8,000 years later.

Clouds. Global warming would produce more of them—but do they enhance or retard the greenhouse effect? The most recent information from NASA's Earth Radiation Budget Experiment satellite revealed unequivocally that the net effect of clouds is to cool the earth.

The sulfur dioxide question. Smokestack industries put millions of tons of sulfur dioxide into the air every year. And according to Patrick Michaels, an environmental science professor at the University of Virginia, this substance is a global cooler. "Perturb the climate with carbon dioxide alone," Michaels says, "and you get global warming. Perturb it with sulfur dioxide alone, and you get an ice age." Taken together, Michaels theorizes, these pollutants could have self-canceling effects.

Beneficial effects. Recent studies suggest that global warming, if it occurs, could actually benefit agriculture. By extending growing seasons, says the National Research Council's John Perry, warming would mean "more wheat in the Ukraine. Thinner ice in the arctic. Better winters in Moscow." Carbon dioxide, moreover, is a widely used fertilizer that accelerates plant growth and enhances crop yields. According to a recent analysis involving scientists from eight universities, these factors could increase American farm income by $3.5 billion.

Thanks to these uncertainties, scientific opinion on global warming is bouncing around like a weather balloon in a

Fact Sheets

4.20 The Greenhouse Question (con't.)

thundercloud. But while researchers fret among themselves, many keep silent as the public is fed a steady diet of doom and gloom. Why?

"You tell me where a man gits his corn pone," wrote Twain, "and I'll tell you what his 'pinions is." Global warming has spawned a multi-billion-dollar industry that gets its corn pone from greenhouse greenbacks, including more than $1 billion in federal funds and many millions from private foundations. New private organizations, such as the Climate Institute, the Center for Global Change, and the Center for Clean Air Policy, are springing into existence to feed at this trough. Conservation think-tanks, like Worldwatch Institute (generously helped by the Rockefeller Brothers Fund) and the World Resources Institute (beneficiary of more than $25 million from the MacArthur Foundation), make a living on the issue. The Bureau of National Affairs, with offices in several countries, publishes *World Climate Change Report*, a thick monthly newsletter with a subscription price of $682 a year, simply to report on meetings and research in this fast-developing field. Global warming has become for climatologists what the atomic bomb was for physicists in the 1940s: a big-buck bonanza.

Many of these measures are necessary, but nothing will be gained if we lose our cool.

But financial incentives can compromise scientific objectivity. Grants and research contracts go to those researchers who emphasize threats. (The $100,000 Mitchell Prize, for example, will be awarded next March to the best scholarly paper on "responses to global climate change." Those who do not believe the change has yet arrived need not apply.) This pressure in turn encourages scholars to make premature predictions. Climate modeling in particular is still an infant science, yet it is being asked to make projections on which policy can be based. As Harvard economist Richard Cooper put it at a recent National Academy of Sciences conference on global warming, "Modelers have been thrust into the limelight way too soon. They don't have models today you can build public policy on."

Government agencies, too, use global warming to leverage bigger appropriations. For them, the greenhouse game has become a major industry, involving NOAA, NASA, the National Science Foundation, the United Nations Environmental Programme, and the governments of all major industrial countries. Even the State Department has an Office of Global Change.

These greenhouse professionals are the authors of the "studies by experts" reported in the newspapers. And, as the IPCC gambit demonstrates, in their effort to capture the mind of world opinion they are taking no prisoners. Making predictions right out of the Book of Revelation, they are orchestrating a rising tide of public concern that is pushing world leaders relentlessly toward an unknown future.

LAST JUNE, JOHN MADDOX, EDITORIAL writer for *Nature*, wrote, "Computer climatic models are still shot through with uncertainties...but...there is a much greater uncertainty about the economic consequences of greenhouse-gas restriction."

Common prescriptions for reducing greenhouse emissions include levying "carbon dioxide taxes" on fossil fuels, switching to natural gas and back to nuclear power, phasing out gasoline, putting more insulation in buildings, stepping up public transportation, developing "clean coal" technologies, and expanding sources of solar and wind power. These steps, say advocates, would reduce carbon dioxide output 20 percent in 20 years.

Many of these measures are good and necessary, regardless of the truth or falsity of the greenhouse hypothesis. But nothing will be gained if we lose our cool. According to the *New York Times*, achieving a 20 percent reduction in greenhouse gas emissions in the United States would rack up costs equal to defense spending. It almost certainly would require heavier reliance on nuclear power, giving a competitive economic advantage to European countries such as France and Germany, which already depend more on nuclear power and less on fossil fuels than we do—a reason, some economists argue, why Europeans are more willing to reduce carbon dioxide emissions. Yet a 20 percent rollback in greenhouse gas emissions would have virtually no effect on global warming. Averting the big cookout, scientists say, could require as much as a 90 percent reduction—necessitating draconian policy measures such as the one that Jonathan Porritt, director of England's chapter of Friends of the Earth, recently recommended to me: the creation of "an international agency with enforcement powers to keep each country on an assigned carbon budget."

To take such a large and uncertain step at this point, to risk human economies and liberties for the sake of a problematic hypothesis, is to abandon reason as a tool for coping with environmental crisis.

The earth, suggests James Lovelock in his book *Gaia*, has the capacity to react appropriately to threats, thereby preserving conditions that sustain life. And humans, he says, through their ability to "channel and process information," are part of this feedback loop. This requires a complex interplay among social institutions: Science must identify changes in the environment and assess the relative risks. Environmental lobbyists and the news media must accurately relay these assessments to lawmakers. And governments must fashion appropriate policies. But the global warming controversy highlights the fact that this system is not working.

Last year, Senator Albert Gore of Tennessee, a leading congressional proponent of the greenhouse theory, told *Time* magazine, "Those who, for the purpose of maintaining balance in the debate, take the contrarian view that there is significant uncertainty about whether global warming is real are hurting our ability to respond." Likewise, climatologist Stephen Schneider, also a greenhouse theory advocate, remarked last year in an interview for *Discover* magazine that scientists such as himself "need to get some broad-based support, to capture the public imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. Each of us has to decide what the right balance is between being effective and being honest."

These men are not just urging us to leap before we look. Gore would turn belief in global warming into a test of environmental commitment. Schneider would trade truth for political expediency. But honest doubt is not a sign of ecological indifference, and truth is not negotiable. They are the stuff on which survival depends.

Programs

5.1 Global Change Fact Sheets

Audience: students/communities/scientists/ people requesting information

Duration: 5–15 minutes

Interpretive Technique: 2–4 page fact sheet

Materials Needed: desktop publishing equipment

Program Objectives: To provide information to people seeking relatively in-depth information on global change concepts.

To present sound explanations of how global change is being studied in a region, and varying predictions relating to its regional impacts.

Global Change in the Great Lakes Scenarios, a set of fact sheets developed by the Ohio Sea Grant Education Program, fulfills these objectives. Such fact sheets are becoming a universal mechanism for presenting and distributing detailed information.

The topics covered in fact sheets can range in scope from general ("What is Global Change?") to specific ("How Could Global Change Affect Wildlife in the Everglades?"). Fact sheets allow parks to develop low budget, yet quality, desktop published items targeted to select clientele.

Because global change issues are often difficult to understand, many people — including important decision-makers — are hesitant to support global change policy suggestions by the scientific community. Instead, these people take a "wait and see" attitude toward global change that, unfortunately, defeats the purpose of any proactive suggestions the scientific community may offer.

The Ohio Sea Grant Education Program has produced a series of short fact sheets designed to help people understand how global change may affect the Great Lakes region. By explaining the possible implications of global change for this region of the world, it is hoped that policy-makers and individuals will be more inclined to make responsible decisions about global change policy issues. The publications, called "scenarios," describe the scientific community's prevailing interpretations of what may happen to the Great Lakes region in the face of global warming. The scenarios are written in terms the public can understand. They include the most recent information available on a variety of subjects, and their content has been reviewed for accuracy by a panel of experts. These materials can serve as models for other regions of the world.

List of Titles Included in the Series

Introduction Global Change in the Great Lakes: Understanding Climate Models

Scenario #1 Global Change in the Great Lakes: How Will Water Resources in the Great Lakes Region be Affected?

Scenario #2 Global Change in the Great Lakes: Will Biological Diversity in the Great Lakes Region Suffer?

Scenario #3 Global Change in the Great Lakes: What Could Happen to Great Lakes Shipping?

Scenario #4 Global Change in the Great Lakes: How Will Agriculture in the Great Lakes Region be Affected?

Scenario #5 Global Change in the Great Lakes: Will it Affect Airborne Circulation of Toxins?

Scenario #6 Global Change in the Great Lakes: What are the Implications of Low Water Levels in Great Lakes Estuaries?

Scenario #7 Global Change in the Great Lakes: Will it Speed Eutrophication in the Great Lakes?

Scenario #8 Global Change in the Great Lakes: What Could Happen to Great Lakes Recreation?

Scenario #9 Global Change in the Great Lakes: How Could Fish Populations in the Great Lakes be Affected?

Scenario #10 Global Change in the Great Lakes: How Will Forests in the Great Lakes Region be Affected?

Programs

5.1 Global Change Fact...(con't.)

The Ohio Sea Grant Education Program at Ohio State University has produced 10 scenarios about global change in the Great Lakes (under grant NA90AA-D-SG496, project E/AID-2) in cooperation with the University's School of Natural Resources and Department of Educational Studies. Dr. Rosanne W. Fortner was the project director; Barbara K. Garrison and Arrye R. Rosser were series editors. Production assistance was provided from the Ohio Sea Grant Communications Program by Sue Abbati for design and Maran Brainard for coordination. For more information about these scenarios contact the Ohio Sea Grant Education Program (59 Ramseyer Hall, 29 W. Woodruff Avenue, Columbus, OH 43210-1077).

The scenarios, each two to four pages long, are written for educators, policy-makers and the "concerned" public. The scenarios are packaged in a folder available for $6 (includes postage and handling). If you are placing an order from outside the U.S., please add $3 to cover the additional postage charge. Make payment payable to the Ohio State University in U.S. dollars. Mail your request and payment to:

Ohio Sea Grant – Publications
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212-1194

Programs

5.2 Site Bulletin Example*

(Park Name) NATIONAL PARK

Global Change & Coral Reef Systems

INTRODUCTION

Whether you've experienced first-hand the splendor and beauty of a coral reef by scuba diving or snorkeling, or admired it from afar through a glass bottomed boat, a visit to a local aquarium, a video or book, most would agree that a coral reef treats the senses to a symphony of color and movement. The reef is teeming with diversity of life. Brightly colored clown fish dart in and out of the sea anemones as do other reef dwellers such as trigger fish and parrot fish. Spiney lobsters can be seen crawling along the base of the coral structures searching out their next meal. The coral, bursting in a kaleidoscope of color, is the foundation to one of the most stable ecosystems on earth.

The coral reef ecosystem, one of the most diverse and complex systems on earth, is in serious trouble. Like many habitats on earth, it is suffering the potential effects of global change. Global change refers to the unnatural changes brought about by increased warming of the earth due to excess atmospheric gases. Vast stretches of reef may "bleach out" and become destroyed if global warming does occur. There is much yet to be learned about global change and its effects throughout our planet. Our National Park System, realizing that the future of our coral reefs is at stake, has embarked on a research program to identify the potential effects of global change on coral reefs in hopes of learning ways to prevent further reef destruction. What does the future hold for our reef systems and what part do we play in their survival?

CORAL REEF ECOSYSTEMS & THEIR CONTRIBUTIONS

The coral polyp, about the size of a pinhead, in and of itself is a rather unassuming character, but put a few together under the "right conditions" and you'll have an architectural delight that would put Frank Lloyd Wright to shame! While not all corals build reefs, those that do have the capability of building structures that would over shadow even the tallest buildings in the New York City skyline!

To survive, coral polyps secrete a hard substance called calcium carbonate which really serves as its skeleton and suit of armor. A unique organism, which is more plant than animal called zooxanthellae (alga), lives inside the polyps and acts as a helpmate in the reef building process. Real teamwork in progress! In return, the alga has access to sunlight — a requirement for its survival. Corals build upon their ancestors' reefs, which provide a secure basis of life for current inhabitants. Corals come in a vast array of color, shapes and sizes. A beautiful sight to behold!

The benefits of the reef ecosystem are impressive. First, they provide protection for tropical islands from wave erosion caused by strong weather patterns. Seaweed and lime from old, deceased coral formations provide farmers with plant fertilizers. Because of its biodiversity and beauty, coral reefs attract eco-tourists. A variety of reef dwellers such as flounder and lobster provide food for humans and other marine life. A very important benefit is that of medicines developed from creatures that live on or near the reef. The coral reef, abundant in its diversity, is still much of a mystery. There is much more yet to discover!

*Refer to "Site Bulletins: Supplementary Graphics systems" for NPS site bulletin standards.

Programs

5.2 Site Bulletin...(con't)

GLOBAL CHANGE & THREATS TO THE REEF SYSTEM

What is global change? It is the sum of forces both natural and human-induced that influence the natural systems of the Earth. Such forces include: climatic fluctuations; increasing world populations that depend on resources like water, soil, plants and animals for their daily existence; and humans' increased usage of fossil fuels like coal and oil. These further stress our Earth in the form of global warming and ozone depletion. The list goes on and on! Scientists and world leaders are quickly discovering that all of these phenomena are putting stress on our worldly environment. How much stress can our ecosystems endure?

Specifically, coral reefs are experiencing serious threats to their existence. Water pollution can be deadly to coral polyps. Chemicals from sewage and oil spills travel through water systems and eventually reach the reefs only to destroy coral polyps. Related to that issue is the increase in ocean temperature. Such a rise causes the "bleaching out" of coral. This phenomenon, which can be lethal, disrupts the teamwork between the polyps and algae residing in the polyps. Additionally, sediment build-up, caused by shore development and erosion, threatens the coral's survival. Suspended silt blocks out the sunlight needed for coral growth. The fishing industry and cruise ships contribute their share to reef destruction when dragging their anchors along reefs. Can you think of other threats to the reef system?

YOUR PARK'S ROLE IN GLOBAL CHANGE MANAGEMENT

The relationship between global change and the coral reef ecosystem still remains much of a mystery. However, global change researchers, realizing the importance of attaining a better understanding of this relationship, have embarked on a complex and systematic research adventure. It is their belief that with a thorough understanding of the interrelationships between global change and the reef system, solutions will follow to help protect reefs from further damage. The research centers on:

1. evaluating the effects of land form and weather on sea surface temperatures adjacent to coral reefs;
2. evaluating the effects of the environment on site conditions and new reef growth;
3. establishing long–term observation sites to gather evidence on the incidence of coral death, coral community structure and growth;
4. documenting the effects of temperature, carbon dioxide and ultraviolet light on growth patterns and skeletal composition of reef systems; and
5. evaluating the effects of light and temperature on incidence and recovery of bleaching corals.

The goal of such a site–specific research plan is to attain a level of knowledge that will empower scientists, park systems and each of us to implement plans to protect one of the Earth's wondrous treasures.

YOU MAKE A DIFFERENCE!

While research will provide answers to help implement protection plans, you play a very important part in the preservation of the coral reef systems. You can make a difference by:

1. Gentler tourism — If you decide to visit up close, refrain from touching or breaking the fragile coral structures.
2. Support respectful development — Know what is being built along shorelines and become an activist for responsible development.
3. While vacationing leave the shells and sea treasures on the beach — they only gather dust at home!
4. Capture the beauty of the reefs on film instead of taking souvenirs.
5. Discourage the harvest of reef fish for private aquariums.
6. Learn more about global warming trends and how you can help by reducing use of fossil fuels.

These are but a few strategies to sustain and enhance diversity of life in and around coral reefs. Can you think of others?

Visit your local aquarium and library. They are havens for learning more about the mysteries of the deep.

Suggested readings:
Coral Reefs by Dwight Holing
Start Exploring Oceans by
Diane M. Tyler & James C. Tyler.

Contributed by *Susan Setterlin*, student
Natural Resources 610 Project
School of Natural Resources
The Ohio State University

Programs

5.3 Sample Program

Audience: school groups/communities/park visitors

Duration: 30 minutes–1 hour

Interpretive Technique: puppet show and slide presentation

Materials Needed: stage and bench
- tape deck
- George Winston's "Winter into Spring" cassette tape
- ocean cassette tape
- cards with place names
- five puppets
- lamp or candle, crystal ball
- four cards with letters S, E, A, and Z (one letter on each)
- wall calendar
- park brochures and newspapers
- two slide projectors and carousels of slides

Program Objectives: To introduce the audience to global change issues in an entertaining manner using analogies to illustrate different concepts.

To link global change to local and regional issues.

At Redwood National Park a unique interpretative program has been developed that brings global and local climate change issues together. The following is a description provided by the author:

This program is a trilogy of three stories. The first two stories are about local subjects — tidepool zonation and redwood zonation. The last is the story of the global human zone.

Each story uses the same plot and moral (theme message). Only the characters and subject matter change.

The first story is told with puppets. It's the story of a traveler who leaves home on a quest. The experiences of the journey teach the traveler the value of what was left behind. It's a global myth (an almost universal cultural paradigm) that is found in folktales around the world and thus I feel all audiences can relate to it. The plot turned the variety of subject matter (tidal zonation, redwood natural history, space exploration ...) into a story with a moral (or should I say, a program with a theme message).

A slide presentation illustrates both the second story — Redwood zonation, and the third story — human zonation.

The moral of the story is "There's no place like zone ... your own." I hope visitors will conclude for themselves that our zone (Earth) is all we have and the changes we are making to our zone could lead us down the same trail as the dinosaurs and the redwoods.

For information on the complete program, contact:

Jay Moeller, Supervisory Park Ranger
Redwood National Park
1111 2nd St.
Crescent City, CA 95531
707/464-6101

Programs

5.4 Brochure Insert

Audience: park visitors

Duration: 10 minutes

Interpretive Technique: Brochure insert

Materials Needed: printer capable of custom cutting and printing specific sized inserts

Program Objects: To supplement existing on-site brochure (primary park brochure, self-guided trail brochure, etc.) with global change subtheme information.

One technique for effectively and inexpensively adding global change messages to existing trail or topical brochures is through brochure inserts. Printed material on light weight cardstock may easily be slipped into two, three or other multiple fold brochures. Typically, brochure inserts are 8.5 x 3.5 (or less) inches and are printed on both sides. Double-sided printing of multiple brochure inserts on a master page requires the front and back panels to be carefully registered (matched) to ensure that minimum margins and thus maximum text/graphic space are available.

Brochure inserts may very well contain information that would fit within the NPS site bulletin concept. A rationale for the brochure insert is to ensure that global change is integrated into an existing theme. For example, a coastal unit interpreting the relationships among marine environments, tidal zones, coastal barriers, etc. using a brochure or trail guide may wish to include a brochure insert. Such an insert might include the following information:

GLOBAL CHANGE AND SEA LEVEL RISE

Factors Affecting Sea Level
Changes in the level of the world's seas have been the focus of considerable debate. The level of the seas has, however, fluctuated throughout the history of planet Earth. Geologic and climatic factors influence sea level. Rapid movements in the Earth's unlying tectonic plates or glacial melting result in a sea level rise. Geological factors are, however, usually slow processes and are unlikely to greatly affect sea level rise in an accelerated manner.

Climatic factors are quite different. There are two ways in which the world's climate affects sea level: first, by disturbing the balance between water locked up in glaciers and in liquid form, and second, by changing the temperature of the oceans.

As the temperature of water increases, the volume also increases. This fact has been known for a long time, but only recently has it been applied to the seas. Even if the glaciers did not melt as a result of global warming, the simple increase in global temperature would cause an increase in the volume of the world's seas and consequently a rise in sea level. While it is true that it would take hundreds of years to warm the entire ocean system of Earth, the upper layers would be warmed and could cause as much as a one meter rise in sea level in just 20 years. Such sea level rise would have major impacts on coastal national parks and monuments.

History of Sea Level Rise
During the height of the last major ice age (12,000–20,000 years ago) sea level was about 100–150 meters lower than it is today because so much of the planet's water was in the form of ice in glaciers on land. Temperature and sea level rose to today's levels during the warm interglacial periods. From the end of the last ice age to about 6,000 years ago, the seas rose at a rate of about one centimeter per year.

Tidal gauges designed to measure sea level have been used at various locations around the world for about the last 100 years. Scientists who have analyzed the measurements of these gauges have determined that during the last century worldwide sea level has risen 10–15 centimeters.

(side 1)

Programs

5.4 Brochure...(con't.)

The Greenhouse Effect and Sea Level Rise

Human impact on the Earth's temperature may upset the stability that has existed between climate and sea level. We may be causing the planet to warm at a rate far too fast to allow for the evolution of natural systems.

The main problem appears to be a dependence on the burning of fossil fuels. The burning of fossil fuels releases carbon, stored for millions of years, into the atmosphere. Carbon dioxide (CO_2) has been identified as the major contributor to the warming of Earth. The National Academy of Science has estimated that doubling the amount of CO_2 in the atmosphere could result in a 1.5–4° Celsius increase in the world's temperature and significant sea level rise.

Most of the planet is water, with land above sea level occupying only a small portion of the globe. Any significant rise in sea level is cause for alarm, especially considering the amount of development, both residential and industrial, near coastlines.

Effects of Sea Level Rise

A sea level rise would have numerous consequences. Among them are: 1) inundation of shorelines; 2) salt intrusions; 3) increased erosion; and 4) increased flooding. Those areas currently at or near sea level, such as Miami, Florida; Everglades National Park; New Orleans, Louisiana; and others could become our first underwater cities and parks.

Freshwater marshes and wetlands, some of which are considered to represent levels of biological diversity and importance unsurpassed in the world, would succumb to increases in saltiness of their waters. Aquifers supplying groundwater to coastal cities could have their freshwater increasingly replaced by saltwater. Finally, those areas not normally subjected to extreme flooding, such as Sacramento, California and Baton Rouge, Louisiana, could find themselves beach front properties.

Such issues, although not yet certainties, require the National Park Service to engage in research and monitoring activities to assess potential impacts. Likewise, each person must engage in educational activities to learn more about the issue and what each person can do to reduce potential impacts.

(side 2)

Sea Level text contributed by Rosanne W. Fortner and Nick Sebasto–Smith, School of Natural Resources, The Ohio State University.

5.5 Global Change Activities

Audience: middle/high school students

Duration: 30 minutes - 1 hour plus

Interpretive Technique: environmental / science education activities

Materials Needed: varies depending on activity

Program Objectives: To provide students, as future decision makers and leaders, with an opportunity to explore and better understand the concepts and potential consequences of global environmental change.

Global change activities for middle and high school age students (and adaptable for park visitiors) provide an excellent opportunity for targeting messages to our nation's future decision-makers. Likewise, such activities provide background for developing more general public education/ interpretive programs.

"Activities for the Changing Earth System — Curriculum Activities for Teaching About Global Environmental Changes" provides such material. Designed as a resource book for middle and high school programs by the College of Education, School of Natural Resources and the Byrd Polar Research Center of the Ohio State University, the activity book includes nearly 300 pages of materials most relevant to the NPS Communicating Critical Resource Issues program.

The project, directed by Drs. Rosanne W. Fortner and Victor J. Mayer under a grant from the National Science Foundation, includes activities, fact sheets and source materials. The Table of Contents, information on how to order and a sample "Technology Fact Sheet" are included.

Contents of the document are:

How To Order

ACTIVITIES FOR THE CHANGING EARTH SYSTEM (ACES) 1993

A book of 20 activities for middle and high school students using an integrated approach to teach concepts in Earth, Biological and Environmental Sciences.

• Tested activities that are classroom ready.

Each activity is organized to include: Objectives, Earth Systems Understandings, Procedures, Extensions, Teacher Background Information and References.

5.5 Global Change...(con't.)

Activities for global change topics in ACES include:

- greenhouse gases and global warming;
- ozone depletion;
- shrinking freshwater resources;
- deforestation;
- rising sea levels;
- volcanic eruptions and global climate change.

Recent scientific information from federal and non-governmental agencies was used in the development of board games, use of proxy data to examine climate change, experiments, role play simulations and extensive resource lists.

To order a copy of ACES (300 pp.), please complete the following information and mail a check or money order for $10 per copy plus handling and shipping to: Earth Systems Education Program, The Ohio State University, 59 Ramseyer Hall, 29 W. Woodruff Ave., Columbus, OH 43210. Phone: 614/292-3750

Name: ______________________

Position: ______________________

Address: ______________________

Telephone No.: ______________________

Number of Copies @ $10 (plus $2 per copy for shipping and handling): ______________________

Locations outside U.S. include $4 for shipping and handling. Payment in U.S. dollars only.

Amount enclosed: U.S. $ ______________________

Sample Activity

INTERACTING WITH AN ON-LINE DATABASE: EcoNet

On-line databases are ready-to-use databases accessible to anyone with a telephone line, a modem, a computer and any computer software that is designed for the computer and able to interact with the modem. If this equipment is available to you, and if everything is setup properly, you can simply use the telephone line to access any on-line database. All you need to know at this point is a telephone number, some parameter settings for the modem and some knowledge about the database you are accessing.

A good way to learn how to access an on-line database is to experiment with one during an actual live session. As an example, consider EcoNet, the International Computer Network for Information related to Environment and Education. With EcoNet, you can access information pertaining to education and the environment by electronic mail, news or conferences. To do this, simply go through the steps provided for you in the setup and interaction procedures.

SETUP PROCEDURE:

1. Make sure everything is turned on and ready to go.

2. Change the modem's parameters to meet the on-line database's specifications. For EcoNet, the parameters are as follows:

   - Full Duplex
   - 7 Data Bits
   - 1 Stop Bit (2 stop bits for 300 baud)
   - Odd Parity
   - Other parameters (such as baud rate) depend on the particular modem being used.

3. With your modem dial the telephone number of the on-line database. Also, be aware that some on-line databases have different telephone numbers for

5.5 Global Change...(con't.)

different modem speeds (baud rates). For Econet, the phone numbers (in Ohio) are:

- Cleveland, OH (area code 216):
  575-1658 (300/1200 Baud)
  771-6480 (2400 Baud)

- Columbus, OH (area code 614):
  463-9340 (300/1200 Baud)
  461-9044 (2400 Baud)

NOTE: Some on-line databases require access information such as an access code, a login name, or a password. EcoNet requires a login code and a password in order for its system to be used. For EcoNet's login information, contact:

Institute for Global Communications
3228 Sacramento Street
San Francisco, CA 94115
415/923-0900.

INTERACTION PROCEDURE:

1. After dialing EcoNet, you should see the word "CONNECT" on your computer monitor (if you don't see "CONNECT", try dialing again or check your equipment). After the "CONNECT" prompt do the following:

For (1200 Baud):
- Press <RETURN> twice.
- After the "Terminal =" prompt, hit <RETURN>.
- After the "@" prompt, enter: 408346 and hit <RETURN>.

For (2400 Baud):
- Type @ and press <RETURN>.
- After the "Terminal =" prompt, hit <RETURN>.
- After the "@" prompt, enter: 408346 and hit <RETURN>.

Before you continue, be sure to use lower case letters!

Now you are ready to enter your login access code. Following the "login: (? for help):" prompt, enter your login access name. After the "Password: (? for help):" prompt, enter your password (xxxx's will appear as you enter it).

2. You should now see a "Terminal = generic (press <RETURN> or enter new terminal type):" prompt. After this prompt, press <RETURN>.

3. You should now see the following options:
(c)onf (h)elp (m)ail (s)etup (u)sers bye.
You can try any of these options by entering their corresponding letters and pressing <RETURN>. For now, however, enter: c and press <RETURN> to get into the conferences.

4. Enter: ? and press <RETURN> for the list of available commands. You should now see:

g - go to conference
l - list conferences
v - visit the next regular conference
q - quit out of conf
h - provide more help
m - conference list maintenance

5. Enter: l and <RETURN> for a conference list.
- Press <RETURN> for EcoNet after the "Network:(a)ll, (o)ther, etc." prompt.
- After the "Enter name, keyword, etc." prompt, press <RETURN>.
- Following the "Do you want: a (s)hort, (m)edium, or (l)ong listing etc." prompt, enter: s and press <RETURN> for a short listing of conferences. (If your modem, software and computer are properly communicating with one another, you should see a legible list of conferences).

6. Before you select a conference, you must press <RETURN> to quit the list of conferences. Now you can select any conference from the list you generated. As an example, consider the conference called 'en.wildlife'. After the "Conf?" prompt, enter: en.wildlife and hit <RETURN>.
7. On the monitor, you should see how many unread topics and responses there are for the en.wildlife conference. While you are in the conference mode,

Programs

5.5 Global Change...(con't.)

any time you enter a '?', you will be given the list of command options for conferences. Enter: ? and press <RETURN> to view the list. You should now see:

- To read a topic, type its number.
- To read a response, type the topic number, then a period, then the response number (for example, 14.5 displays response 5 of topic 14).

Basic Commands (use the 'help' command for more extensive help).

b/f (b)ackward / (f)orward one page.
u show next (u)nread message.
t show next unread (t)opic.
v (v)isit next regular conference.
q (q)uit from conf.
i show (i)ndex page — (all topics).
c (c)apture commands (e.g. kermit).

8. For this session, enter: i and <RETURN> for an index of all the topics in the en.wildlife conference.

9. After you have looked over the various topics in the en.wildlife conference, you can select any topic at all by using the basic commands that you have just listed. You will most likely use b, f, u, and t. Or, you can type the number of the topic you wish to view followed by pressing <RETURN> (remember, from #7 on the previous page, you were given the total number of topics in the en.wildlife conference. So if there are 123 topics, the numbers you use to select a topic must be from 1 to 123).

10. You can also visit the next conference via the v command. If you do this, you might want to get an index of all the topics in that conference since it will be different than the en.wildlife conference.

11. If you are finished viewing conferences, you can exit the conference mode by typing 'q' and pressing <RETURN> after the "Conf?" prompt.

12. You should now see the EcoNet commands:
(c)onf (h)elp (m)ail (s)etup (u)sers bye.

NOTE: At some other time, you might want to continue by selecting any of these commands. To get a printout of the information you have acquired, you need to be familiar with your modem and the software you are using, so consult those manuals.

For this session, however, enter: bye and press <RETURN>.

You have just successfully interacted with an on-line database!

Programs

5.6 Global Change Educational Activities

Audience: students in grades 7–10, or adapted to other age groups and ability levels

Duration: 40–60 minutes for each activity

Interpretive Technique: environmental education activities

Materials Needed: varies depending on activity

Program Objectives: To inform students about global change.

To apply scientific knowledge to real world problems.

To demonstrate interconnections between science, society and the environment.

Several environmental education curricula now available contain units of programs dedicated to the exploration of global change. "Global Warming and the Greenhouse Effect" (*Great Explorations in Math and Science*, Lawrence Hall of Science, University of California at Berkeley, 1990) by the Regents of the University of California provides several hands-on activities suitable for use in parks as well as classrooms. With a little creativity, these activities can be adapted to reach a wider audience and to address localized or regional issues.

Eight different lessons (or sessions) are included in Global Warming and the Greenhouse Effect. Those activities are as follows:

Session 1: What Have You Heard About the Greenhouse Effect?
Session 2: Modeling the Greenhouse Effect
Session 3: The Global Warming Game
Session 4: Detecting Carbon Dioxide
Session 5: Sources of Carbon Dioxide in the Atmosphere
Session 6: Changes on Noua's Island
Session 7: The Worldwide Effects of Climate Change
Session 8: World Conference on Global Change

The activities range in their level of participation and material usage. A partial summary outline of Session 1 is presented as an example of how these educational activities are structured. (The guide also includes technical and scientific information to aid communicators.)

Session 1: What Have You Heard About the Greenhouse Effect?

On the Day of the Activity

1. Tape butcher paper to the wall.
2. Set aside sentence strips and masking tape.
3. Organize the room for groups of students.

Writing About the Greenhouse Effect

1. Tell students you want to find out what they know about the greenhouse effect and how it may warm the Earth.
2. This is how scientists start an investigation.
3. Ask students to think about anything they've heard.
4. Students have three minutes to make their lists.
5. Students may draw pictures, then describe in words.
6. Questions on other side.

The "Mind-Swap"

1. Students work in teams of three or four to share information.
2. Explain rules:
   a. No interruptions as one student shares.
   b. Next person says only what was not covered by previous.
   c. When everyone has shared, teams ask questions and discuss.

Discussing What We've Heard

1. Call on each group — one thing they've heard or know.
2. Discuss disagreements.
3. During unit, class will consider accuracy of listed statements.
4. If "hole" in ozone layer listed, explain it is NOT cause of greenhouse effect.

Programs

5.6 Global Change Educational...(con't.)

What We Don't Know About the Greenhouse Effect

1. Groups discuss questions; each person writes one question on sentence strip.
2. Consider a question if no one in group knows answer.
3. Distribute strips of paper and marking pens.
4. Students post questions on the wall.
5. Ask students if they can answer any of the questions posted.
6. Scienti.,ts do not know all the answers about global warming; students are learning with the scientists! Will return to questions later.

Thinking About Climate Change

1. Ask about evidence of climate change, such as where students live.
2. Some scientists believe average temperature of Earth is increasing. Ask students how to measure average temperature.
3. Hand out graph on average temperature. Ask volunteer to read scales of upper graph.
4. What happened to temperature over past 100 years?
5. Scientists concerned about rising temperatures, this is already a warm period for the Earth.
6. Ask volunteer to read the scales in lower graph.
7. Ask students to describe how temperature has changed over past 450,000 years.
8. Discuss Ice Ages. When was last interglacial period?
9. Students meet in small groups to discuss: How many interglacial periods in past 100,000 years? How long in the current warm period? How much has temperature risen in past 110 years?
10. Discuss answers with entire class.
11. Some scientists say Earth will cool off and we'll have another Ice Age; others say that the Earth will be warmer by the middle of next century.

To purchase *Global Warming and the Greenhouse Effect* contact:

Great Explorations in Math and Science (GEMS)
Lawrence Hall of Science
University of California
Berkeley, CA 94720
510/642-7771 — call for up-to-date price list

Programs

5.7 Interpreting Park Science

Audience: multiple age, multiple social relationship groups/student groups/community groups

Duration: 30 minutes – 2 hours

Interpretive Technique: guided activity/lecture/ campfire presentation

Materials Needed: varies with techique

Program Objective: To help park visitors grasp the significance of the global change issues as it relates to national parks and better understand the role of scientists today in the study of the park and the world.

Interpretive myth holds that most visitors are not interested in the "science" of the park, only in very light, enjoyable topics. Experience at several parks relating to acid deposition/air quality programs proved this wrong. A recent national poll indicated that more than 25 percent of U.S. citizens consider themselves avid consumers of scientific information. This, combined with the fact that NPS visitors are, for the most part, very well educated, should help dispel the myth. Perhaps visitors are interested in science but not boring science.

Science in the national parks, whether natural, cultural or historical factors are interpreted, is anything but boring (i.e., "only people can be boring; subject matter in and of itself is not boring" —*anonymous*). The ongoing NPS/NBS inventorying, monitoring and evaluation studies supply extensive information for NPS interpretive programs.

Currently NPS has 20 biogeographic global change areas designated as research sites. Each of those areas has an ongoing or planned global change research program. Much of those efforts are outlined in "Global Change Research in U.S. National Parks" (see Section 3.1).

Other research — acid deposition/air quality, biological diversity, species specific studies, human impact assessments — is ongoing in the national parks and most is global change-related. With the cooperation of park researchers, site visits to research areas as well as guest presentations by scientists can be rewarding experiences for the visitor.

Whether one is monitoring changes on a coral reef off the coast of Florida, learning about the air quality equipment along the Blue Ridge Parkway or observing ozone studies in the Great Smoky Mountains, the information is rich.

A variety of program options exists:

- Take the visitors to a field research site.
- Bring researchers to the amphitheater or auditorium for guest presentations.
- Engage audience in volunteer inventory work such as a butterfly monitoring program in Great Basin.

Interpreters can and do make park science "come alive."

One of the best places to begin is with the park or regional scientists. Interpretive training in park science subject matter and related issues by park scientists for interpreters should part of routine and ongoing training. If public education/interpretation is to make a difference, interpretive programs must address more critical resource issues; park science programs are key sources for information.

Programs

5.8 Global Change and Evolution Program or Exhibit

Audience: park/nature center/museum visitors

Duration: 10 minutes – 1 hour

Interpretive Technique: program/program segment/exhibit

Materials Needed: display materials depend upon the amount of detail in the exhibit

Program Objectives: To expose visitors to new theories about how human evolution was in part shaped by global climate change.

Several important steps in the evolution of humans have been marked by changes in global change. Since all life on Earth must adapt and change in order to survive in changing environments, plants and animals have evolved in step with global climate changes. While the changes that climate shifts brought are seen in the evolution of all life, visitors may find it particularly interesting to see how their own existence was probably shaped in part by these global changes. Bringing these ideas to visitors of parks, nature centers or museums (or to countless other types of interpretation audiences) sheds an eye-opening light on the possible effects of global change.

One theory holds that without the dramatic global climate changes caused by a tremendous crash between a meteor and the Earth, human beings might not exist today. It is believed by many scientists that the extinction of dinosaurs resulted from the devastating environmental impacts of a meteor collision with the Earth. The huge amounts of dust that the collision created were sent into the air, bringing about dramatic global climate change. With the dinosaurs gone, a small badgerlike mammal (the ancestor to almost all mammals, including humans) was able to prosper and evolve.

The beginnings of upright walking may have been rooted in the slow global cooling that took place between 100 and seven million years ago. Increased amounts of weathering of rocks caused the Earth to absorb more CO_2 (a greenhouse gas that keeps global temperatures warm) from the atmosphere than it had previously absorbed. The resulting cooler temperatures led to the break up of the lush dense forests of Africa into patches of forests and plains. Walking on two feet made it easier for human ancestors to move between forest patches.

Fluctuations in global climate change that corresponded to astronomical cycles may have been the driving force behind the evolution of the ancient human brain — growing bigger and bigger for more than a million years. About 2.5 million years ago, the global climate began a cycle of warm and cold periods in response to a new sensitivity to the tilt of the Earth's axis as it moved around the sun. The cold periods lasted about 50,000 to 80,000 years, while the warmer "interglacial" periods lasted about 10,000 years. The cycles continue today. We are now nearing the end of a warm period, with the next period of glaciation expected to arrive in about 2,000 years. The idea has been proposed that the warm periods allowed humans to prosper in lush, wet environments, while the colder periods of harsh weather caused only the more intellectually advanced ones to survive. Then in the next warm population boom, the larger-brained human ancestors increased in number. The cycle has repeated at least 15 times in the last 1.6 million years.

Ten thousand years ago, the global temperature began to rise. Sea levels rose quickly and temperatures increased to an average of 59 degrees Centigrade, as compared to 50 degrees Centigrade just a few thousand years earlier. As coastal areas were flooded, many animals became extinct; early humans were forced to give up their nomadic ways. They moved inland and became less migratory. Although they continued to hunt and gather, they also began the practice of agriculture. This was no small happening in the history of human life. With agriculture came a sedentary lifestyle that forced humans to learn new ways of interacting with other humans on a daily basis.

Programs

5.8 Global Change and Evolution...(con't.)

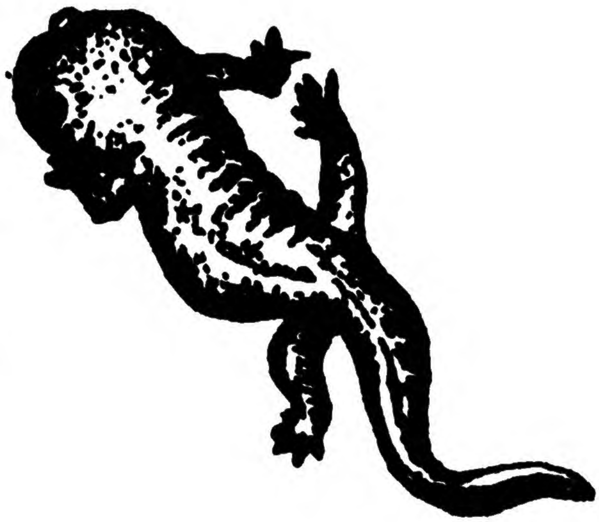
These are only a few examples of how the evolution of human beings may have been partially shaped by global climate changes. Learning that human ancestors and humans have been able to adapt to ever-changing climactic conditions may, rightly or wrongly, ease the minds of some who are worried about global change. Whether global warming due to the actions of human beings is indeed a fact is still disputed. If it is a fact, the nature of life as we know it may change drastically.

These ideas are well suited for an interpretive program or for an exhibit that follows the evolution of humans along with the evolution of global temperatures and natural environments. With a se. of slides, murals and/or three dimensional displays, the impacts of the Earth's climate on how we came to be what we are could be dramatically represented.

The June 8, 1992 issue of *U.S. News and World Report* presents an interesting series of pictures (and story) that could easily be converted into large exhibit pieces that show the Earth's history parallels human history starting 200 plus million years ago. The accompanying article, "Climate and the Rise of Man," also details more examples of simultaneous changes between the climate and humans.

To secure a copy of the issue (June 8, 1992, Volume 112, Number 22) or to inquire about permission to use the article's accompanying artwork, contact:

Editorial and Corporate Offices
U.S. News and World Report
2400 N St., NW
Washington, DC 20037-1196
202/955-2000



Programs

5.9 National Park Environmental Education Program

Audience: students

Duration: varies with activity

Interpretive Technique: environmental education activities

Materials Needed: varies with each activity

Program Objectives: To help students understand how scientists investigate global climate change as a means of equipping students with scientific inquiry skills.
T
o help students understand the complexities of global climatic change.

Glacier National Park's Environmental Education Guide, entitled "Global Climate Change," provides a model to help other parks adapt or develop their own guide or curriculum units. In introducing the Guide the following statement is offered:

> "This unit on Global Climate Change investigates the issues of global warming and the procedures that scientists are using to further our understanding of the global climate system. Background information and activity suggestions are included. Teachers are encouraged to incorporate these activities into daily classroom study before coming to Glacier. When students arrive at the park already possessing a framework of vocabulary and concepts, their field trip experience is greatly enhanced."

Three pre-trip activities ("Classroom Activities"), three in-park activities ("Park Visit Activities") and two post-trip activities ("Back in the Classroom Activities") are contained in the Guide. One activity from each category, as printed in the Guide, is reproduced here. Persons interested in the Environmental Education Guide should contact the Chief Naturalist, Glacier National Park, West Glacier, MT 59936; 406/888-5441.

Classroom Activity 1

Visual Vocabulary

Objective:
Students will be able to interpret and identify ecological concepts related to global climate change.

Method:
Students review vocabulary through use of pantomime.

Background:
The major purpose of this activity is to increase students' familiarity with terms that are important in understanding global climate change issues.

Materials:
Vocabulary list with definitions, small pieces of paper with vocabulary words printed on them, container.

Procedure:
1. Give students handouts with words and definitions on them. Discuss and encourage students to give examples of definitions.
2. List all the words on small pieces of paper and put them in a container.
3. Divide the class into groups of four. Each group draws one word from the container, looks up the definition using the handout, and decides how to pantomime that word. Allow about five minutes for the groups to prepare their mimes.
4. Groups of students then take turns miming their words to the class. Set a time limit of one minute per group.
5. The rest of the class may use the handouts as a guideline for guessing the word being mimed.
6. Groups gain one point for a successful miming (having their word guessed within the one minute time limit) and one point for guessing another group's mime correctly.
7. Continue drawing words as time permits, changing groups or having "star mimers" assist students who muddled their mimes.

Evaluation:
Ask students to choose one of the vocabulary words and draw a picture of its meaning.

Variations:
1. Go outside for this activity.

Programs

5.9 National Park Environmental...(con't.)

Park Visit Activity 3
Village Data

Objective:
Students will utilize the process skills (observing, measuring, interpreting data, formulating hypotheses) and consider the importance of holistic thinking as it relates to global climate change.

Method:
Students will split into teams to collect data in the Apgar Village area and then join forces to interpret the data and formulate hypotheses.

Background:
In their effort to understand the "whole" of our global climate system, scientists are collecting data on many of its different parts. Here are a few examples of the parts that Glacier National Park scientists are studying: Transpiration of trees, amount of nutrients in streams, flow rates of glaciers, species movement, temperature variations in the lakes, depth of snow and reflectivity of snow. Individual scientists choose a particular aspect of the global climate system to research and devote their energy to collecting and interpreting data. Through this process we end up with several individuals, each a specialist in some facet of climate change research, coming together to share their work with each other and to arrive at a synthesis of their various understandings. Trying to create a comprehensive whole out of many small pieces of data is the most challenging part of the global climate change scientists' work. Since the whole system is greater than the sum of its parts, they have to use gestalt thinking to uncover the intangible.

Location:
Apgar Village or the St. Mary area

Materials:
Five clipboards, pencils, paper, a few thermometers and a yardstick.

Procedure:

1. Tell the students that they've been asked to find out what Apgar Village (or St. Mary) is all about, what makes it tick. They are going to split into study teams to gather data on some aspects of the area and then they are going to try to put their data together to understand the whole.
2. Split the students into five groups and provide each group with a clipboard, pencil and paper. Each group is a team of scientists assigned to collect data on a specific aspect of the area. Each team of scientists will design its own data sheets. The group assignments are as follows:
   Group A: Temperature. This group will use the thermometers to take readings at five sites around the area — sunny pavement, shaded pavement, under the trees, on the lakeshore and in the meadow. They may take readings for several different heights at each site with the aid of the yardstick.
   Group B: Animal Species Sample and Count. This group will list all the different animal species they observe during the allotted time, the number of each and where they were located. Remember to include humans and insects in the sample. Signs of animals like tracks, droppings or nests should also be identified.
   Group C: Tree Sample. This group will list all the tree types that they observe in the village, where each type is found and any unusual configurations.
   Group D: Soil. This group will take soil readings at five sites around the area — on the lakeshore, at the intersection outside the Visitor Center, in the center of the cabin area, in the meadow and on the non-paved drive by the creek. They will describe the soil makeup (gravel, needles, stones, etc.), the moisture level at the site and what is growing or living at the site.
   Group E: Building Survey. This group will count the buildings in the area, noting their purpose (residential, commercial, educational, etc.) and their distribution. They might decide to draw a map.
3. When the students have completed their data collection, give each group a few minutes to discuss their findings and decide if an hypothesis can be formulated.
4. Bring the groups back together to share their findings with one another and explore the question of how these findings might combine to describe the area in a comprehensive way (e.g., a

Programs

5.9 National Park Environmental...(con't.)

group hypothesis). What pieces of data could be added to create a clearer picture?

Evaluation:
It is usually easier to collect data than it is to interpret it. When you share it with others, they may view it from a different perspective and argue your interpretation. How do you determine which is right? It could be either, both or a blend of the two. Most of us already know what the jigsaw puzzle is supposed to look like before we start putting the pieces together. What do you do when you haven't seen the picture or the pieces are all one color? You depend on intuition and gestalt thinking. Do you know anyone whose everyday job is to put other's puzzles together for them?

Back in the Classroom Activity 2

Making a Personal Commitment

Objective:
Students will be encouraged to act on what they've learned about Global Climate Change.

Method:
Each student will design a Certificate of Personal Commitment.

Background:
"On Spaceship Earth there are no passengers; everybody is a member of the crew. We have moved into an age in which everybody's activities affect everybody else." Marshall McLuhan

It is easy to become confused and depressed about Global Climate Change when you hear that scientists are still a long way from fully understanding how climate systems work and that world governments are in endless debate over the political implications. In reality, the solution is simple. One major way to control the greenhouse problem is to reduce fossil fuel emissions. Every individual on this planet has a choice in how they use energy — efficiently and with regard for the future, or wastefully.

Location:
Classroom.

Materials:
Construction paper and markers.

Procedure:
1. Ask the students if they would like to change the future. Discuss the fact that it is individuals becoming more efficient energy users that will solve the greenhouse problem and many related problems like acid rain and ozone depletion.
2. There are many excellent resources in books and magazines that describe the various steps that individuals can take to improve their energy efficiency. A few are listed in the bibliography. Discuss these ideas with the students and encourage them to come up with their own ideas as well.
3. Students should select one idea that they wish to act upon. They will design certificates of personal commitment stating what they have agreed to do this year to help solve the greenhouse problem. It could be planting a tree, writing a report to share with the class or biking to their friend's home instead of driving. Display the certificates in a prominent place in the classroom or have the students display them at home.

Evaluation:
The complexities of the modern world make it difficult for individuals to recognize their power. A certificate on the wall is one way to remind ourselves, but in half a year the paper will be faded. We must discover ways to keep the commitment fresh and to remember our power. Have the students think up reminders for themselves. One suggestion might be to write a letter to their future self, restating their plan and asking how it's going. They could seal the letter and entrust it to you to mail to them at some future date.

5.10 Captioned Slides

Audience: adaptable for all audiences where visuals are required

Duration: varies with program

Interpretive Technique: slide presentation or exhibit

Materials Needed: source to copy "for loan" slides

Program Objective: To provide interpreters, and their clients, with a ready set of 35 mm captioned slides on global change.

Captioned slides provide a ready source of background information and visuals to support program development. Individual parks, regions or biogeographic areas focusing on global change issues may wish to develop their own sets of captioned slides on the topic as a means of facilitating global change interpretation.

As an alternative, the Ohio Sea Grant Education Program has made a set of 115 captioned slides available for loan to National Park Service units and has given permission for those to be copied. Although the materials were developed for the Great Lakes region, most slides are not region-specific. If you would like to review and copy the slide set or portions thereof please contact:

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The set of slides will be mailed to you at no charge with a request for a two-week return. Slides may not be used in publications or programs intended for sale without written permission of the Ohio Sea Grant Education Program.

The following provides a description of the slides and the caption information.

Global Change In the Great Lakes:
An Introduction

1: (title slide) Global Change in the Great Lakes

2: (greenhouse effect) The term "greenhouse effect" refers to the increase in the amount of certain gases that have the ability to warm the Earth. Without these gases, life on Earth could not exist. These gases trap heat from the sun, gradually warming our planet. In the diagram, incoming energy from the sun penetrates the atmosphere and heats the surface of the Earth. The warmed surface releases heat in wavelengths that are absorbed by the greenhouse gases in the air. Only a small amount of the gases escapes back to space; the rest are trapped, leading to a warmer Earth. Scientists are concerned about these gases because their presence in the atmosphere has increased as a result of human activities. If greenhouse gases continue to build up, the Earth's temperature could increase by 1.5°C to 4.5°C (2.7°F to 8.1°F) degrees by the year 2060. Precipitation, clouds and winds would also change with this warming. (Source: NOAA and Center for the Great Lakes)

3: (greenhouse gases) This graph depicts the five most critical greenhouse gases and their sources. (Source: American Coal Foundation, 1990)

4: (CO_2 graph) Atmospheric CO_2 measurements taken at the Mauna Loa Observatory in Hawaii constitute the longest continuous record of atmospheric CO_2 concentrations available in the world. The graph shows a 12 percent increase in the mean annual concentration over a 31 year period, 1958 to 1989. (Source: Trends '90, Oak Ridge National Laboratory, Oak Ridge, TN)

5: (systems diagram) When one part of the Earth system changes, the other parts are affected as well. The scenarios describe some of the interactions and their anticipated impact on human activities.

Programs

5.10 Captioned Slides (con't.)

Water Resources

6: (title slide) Water Resources

7: (Great Lakes) The Great Lakes contain 100 million cubic kilometers of water, representing the largest freshwater system in the world.

8: (GL population) Approximately 40 million people live within the Great Lakes basin. (Source: Environment Canada and U.S. EPA, 1987)

9: (water withdrawal graph) Millions of cubic meters of water are used each year in the Great Lakes region. (Source: Environment Canada and U.S. EPA, 1987)

10: (industry) By the year 2020, the demand for Great Lakes water resources will increase eight times for industrial use. (Source: Dr. Andrew White, John Carroll Univ.)

11: (farm) Five times for irrigation use.

12: (cooling tower, Davis-Besse) Most cooling water from older nuclear power plants is returned to the lakes at a slightly warmer temperature. In newer plants it is recycled.

13: (factors affecting GL) Natural factors also affect the levels of the Great Lakes.

14: (hydrologic cycle) Increases in temperature will affect the entire hydrologic cycle, plus all species that depend on it. (Source: Environment Canada and U.S. EPA, 1987)

15: (GL pipeline) Western and southwestern states already require more water than is available to them. Most of this water is used for agricultural irrigation. As the climate changes, they will need to find other sources of water for their region. (Source: International Joint Commission)

16: (Cleveland) Slight drops in lake levels are significant. A 2.5 centimeter decline in Lakes Michigan and Huron is equivalent to more than 36 billion cubic meters of water — enough to supply the needs of a city like Cleveland for over 88 years!

17: (decrease/increase diagram) Global warming will impact Great Lakes hydrology in numerous ways.

Biodiversity

18: (title slide) Biodiversity is the variety of life on Earth.

19: (pie graph/species) No one knows exactly how many species inhabit the Earth.

20: (five fish fighting to survive) Experts estimate that at least one million species will become extinct by the end of this century.

21: (biodiversity reasons) Maintaining biodiversity is important for four main reasons.

22: (Chicago harbor) Habitat destruction caused by human activity is the major factor in the loss of biodiversity.

23: (habitat destruction chart) There are several major causes of habitat destruction in the Great Lakes region.

24: (wetland scene) Global warming will affect biodiversity. If lake levels drop, estuaries and wetlands may decline in quality and quantity.

25: (Canada geese) Decline of wetlands would reduce valuable spawning and breeding grounds for fish and birds.

26: (foam on water) Water quality would decline as pollutants become concentrated in a shrinking amount of water.

[redacted] Programs

5.10 Captioned Slides (con't.)

Shipping

27: (title slide) Shipping

28: (GL map w/cities) Nineteen states and two provinces use the Great Lakes, their locks and the St. Lawrence Seaway for transportation and commercial activity. (Source: Great Lakes Environmental Research Laboratory, NOAA)

29: (boat in channel) Over 200 merchant and foreign flag vessels participate in commerce at 83 ports. The St. Lawrence Seaway generates two jobs for every 1,000 tons of steel moved through the system (nearly 45,000 jobs directly and indirectly). (Source: The Advisor, Great Lakes Commission, Oct.–Nov. 1992)

30: (bulk commerce pie graph) Bulk carriers transport various cargo through the Great Lakes. (Source: Lake Carriers Association, 1990)

31: (products shipped graph) The total amount of products shipped on the Great Lakes has remained fairly constant over the past decade. (Source: Lake Carriers Association, 1988, 1990)

32: (steamship) Lower lake levels resulting from global warming will force cargo vessels to haul lighter loads, making transportation more time-consuming and expensive. (Source: Lake Carriers Association)

33: (ship in port) Lower lake levels would cause ports and connecting channels to be dredged deeper and more often. In addition, dock foundations may be weakened due to lower lake levels. (Source: Lake Carriers Association)

34: (ship with $) Climate change in the future will affect all facets of the Great Lakes economy — shippers, steel producers, grain farmers and other businesses. (Source: Lakes Carriers Association)

Agriculture

35: (title slide) Agriculture (food and fiber production) is basic to the wealth, health and welfare of any country.

36: (land use pie chart) Much of the Great Lakes region is farmed. The eight states alone produce nearly a quarter of the total agricultural output in the United States. (Source: Environment Canada and U.S. EPA)

37: (benefits to agriculture list) If global warming occurs, agriculture may benefit in certain areas.

38: (CO_2 and food quality) However, CO_2 levels in the atmosphere are increasing with global warming and will affect food quality.

39: (Mexican bean beetle larvae) Warmer climatic conditions could increase the activity and range of unwanted insects and plants. (Source: Dr. Harold Willson, Extension entomologist, Ohio State University.)

40: (spraying crops) Farmers may feel compelled to use more herbicides against plant and insect invaders.

41: (farm) A rise in temperature may cause an increase in evaporation, leaving crops with less soil moisture.

42: (lightning) Increases in atmospheric CO_2 will probably result in greater climate variability and could increase the frequency of extreme, climate-related events.

43: (agricultural forecast chart) Agricultural producers now need to consider how future climate could influence regional production opportunities. (Source: University of Guelph, 1987.)

Programs

5.10 Captioned Slides (con't.)

Airborne Toxins

44: (title slide) Airborne Toxins

45: (sky/clouds) The atmosphere is a common pathway by which toxins are contributed to and distributed throughout the Great Lakes.

46: (wind flow across North America) Unfortunately, airborne toxins know no borders. (Source: Sierra Club, et al., 1988.)

47: (lake view) The large surface areas of the Great Lakes have become vast depositories for airborne substances.

48: (food chain) The higher an organism is in the food chain, the greater the number of toxic chemicals it's likely to contain.

49: (biomagnification of PCBs) The longer an organism lives, the more time it has to bioaccumulate poisonous substances in its system. Toxic substances also biomagnify, becoming increasingly concentrated as they pass through the food chain. (Source: Environment Canada and U.S. EPA, 1987.)

50: (critical pollutants) Certain pollutants have been singled out as special problems because they bioaccumulate, biomagnify and have irreversible effects.

51: (PCBs in fish) Airborne toxins are a health hazard for all forms of life, including our own.

52: (surf/beach) Concentrations of pollutants would increase if water levels decreased due to global warming. Storms and surf action would resuspend toxins buried in sand and mud.

53: (heron/wetland) Exposure of toxic sediments in wetlands could threaten waterfowl and shoreline wildlife.

54: (Earth) Airborne toxins can be carried anywhere in the world. Controlling these substances is truly a global responsibility.

Estuaries

55: (title slide) Estuaries

56: (water/sand bar) Estuaries are commonly identified as places where freshwater meets the sea. The chemically distinct waters at the mouths of Great Lakes tributaries are considered estuaries.

57: (water/land) The estuary landscape is composed of a patchwork of wet and dry areas.

58 & 59: (lily pads; estuary scene) Diverse plant communities support a diversity of animals.

60: (estuary values list) Estuaries are important for many reasons.

61: (disappearing estuaries) Today, only 30 percent of the original estuaries, marshes and other wetlands remain in the Great Lakes region. (Source: National Estuarine Research Reserve Program, NOAA.)

62: (condominiums) Shoreline development is just one of the causes of wetland destruction. Others include hydroelectric projects, agricultural development, highway construction and irrigation and flood controls.

63: (chain-reaction funnel) As water levels drop, the future of the Great Lakes region wetlands is in question. In the future, water levels should be monitored continually to interpret the effects of global warming.

Eutrophication

65: (title slide) Eutrophication is a natural aging process for bodies of standing water.

66: (water and grasses) Over time, many oligotrophic (young) lakes and ponds undergo a succession of changes as they become eutrophic.

67: (filled-in pond) If sediments accumulate in a pond or lake, the area becomes a wetland and then moist lowland. This last phase is called senescence.

Programs

5.10 Captioned Slides (con't.)

68: (cultural eutrophication diagram) Human activity can accelerate the rate of aging. This phenomenon is known as cultural eutrophication.

69: (clock) Cultural eutrophication can make a lake old before its time.

70: (seasonal stratification diagram) Lake stratification can accelerate the rate of eutrophication.

71: (decrease/increase diagram) Global warming may increase periods of stratification and negatively affect the lakes.

72: (foam in water) Human impact, especially the problem of identifying non-point source pollution, also affects water quality. (Source: Ohio EPA)

73: (algal bloom) Excess nitrates and phosphates allow algae to grow in abundance, creating an algal bloom.

74: (sailboats) Humans cannot reverse or arrest eutrophication, but proper management can reduce the effects of cultural eutrophication.

Recreation

75: (title slide) Recreation

76: (kids on raft) The Great Lakes states and provinces depend heavily upon income from travel and tourism.

77: (snowmobile) As climatic changes occur with global warming, winter sports will have a shorter season.

78: (cars/parking lot) Increased evaporation rates combined with unpredictable precipitation patterns may shrink smaller lakes in other regions, causing a greater influx of people to the Great Lakes.

79: (fish in seine) Increases in Great Lakes water temperature would affect fish populations. (Source: Dr. Andrew White, John Carroll University.)

80: (boats) Lower lake levels as a result of global warming would negatively affect many recreation activities such as boating;

81: (men with fish) fishing;

82: (canoes) canoeing.

83: (beached boat) Boating is the most economically important activity in the Great Lakes. Lower lake levels would make it difficult for boats to gain dock and berth access.

84: (summer never ends) In the future, the demand for water and water access may place recreation into direct competition with other resource uses.

Fish Populations

85: (title slide) Fish Populations

86: (dredging) Humans primarily affect fish populations by inhibiting their reproduction through habitat destruction.

87: (freshwater drum) Fish are particularly sensitive to changes in the environment and are useful biological indicators.

88 & 89: (species list; sea lamprey) Humans have influenced Great Lakes fish populations by accidentally introducing exotic species.

90: (zebra mussel) Accelerated warming of the lakes may also contribute to the growth of non-indigenous species populations. (Source: John Scarola, New Hampshire Fish and Game Dept.)

91: (dumped barrel) Pollution has been an ongoing problem. People continue to dump toxic chemicals and other waste into the aquatic environment. (Source: Ohio EPA.)

5.10 Captioned Slides (con't.)

92: (preferred habitats) Fish in the Great Lakes generally live in one of three thermal habitats. Each species has a specific thermal niche in which it can attain maximum growth. For example, lake trout prefer cold water, yellow perch and walleye prefer cool water, and bullhead and sunfish prefer warm water.

93: (yellow perch) Global climate change will increase the length of the growing season and amount of suitable thermal habitat for many Great Lakes species. (Source: John Scarola, New Hampshire Fish and Game Dept.)

94: (bullhead) Warmer water temperatures would affect species in a variety of ways. Bottom-dwelling fish, for example, would be forced to relocate during periods of oxygen deprivation in lower sections of the lake. (Source: John Scarola, New Hampshire Fish and Game Dept.)

95: (muddy stream) Fish would be susceptible to increases in runoff, which may occur with changes in precipitation patterns. (Source: Fred L. Snyder, Ohio Sea Grant Extension Program.)

96: (food web) The entire Great Lakes food chain could be affected by global climate change.

Forests

97: (title slide) Forests

98: (forest) Global warming will probably have devastating consequences for many North American trees.

99: (forests and trees) Forests perform many important functions.

100: (models of maple habitat) If global change occurs, northern latitudes could experience warmer climates. In the diagram, the general circulation models (GISS & GFDL) predict responses to increases in CO_2 levels and what this increase could mean for Great Lakes forests. The result could be a northward displacement of ecological zones. (Source: C. Zabinski and M.B. Davis, 1989.)

101: (Buffalo waterfront) The presence of urban areas and extensive farmland in the southern Great Lakes would impede migration.

102: (field) Vast expanses of land with few trees put a strain on tree seed dispersal mechanisms.

103: (acid rain) Pollutants are a contributing factor in forest decline. Higher temperatures would increase the amount of acid precipitation. When temperatures are high, atmospheric nitrogen reacts with oxygen to form nitrous oxide, which oxidizes again to form nitrogen dioxide. When nitrogen oxides meet water, they produce nitric acid (acid rain).

104: (changes in tree species) Possible changes in tree species and size are shown in this diagram. Climate predictions from three general circulation models calculate the impact of the doubling of CO_2 on specific tree species. (Source: D.B. Botkin, R.A. Misbet and T.E. Reynolds, 1989.)

105: (lumber mill) Forest decline could have severe implications for forest industries in the Great Lakes region, such as timber harvesting and manufacturing.

106: (white pine) Softwood species such as pine, fir and birch are currently harvested for the production of pulp, paper and construction supplies.

Programs

5.10 Captioned Slides (con't.)

107: (woman hiking) Recreation and tourism will be economically influenced by forest decline. Forests enhance outdoor activities, which attract thousands of visitors to the region each year.

Conclusion

108: (preparations for change) As global warming occurs, people living in the Great Lakes region can begin to prepare for climate change. Understanding and awareness are the first steps to informed actions.

109: (global warming/land use actions) The effects of global warming on Great Lakes land use can be minimized.

110: (group of people) Biodiversity can be preserved by policy makers and individuals. (Source: Ohio EPA.)

111: (IJC logo) Organizations such as the International Joint Commission are working toward identifying regional water needs in order to make informed decisions for the future.

112: (whose problem) Humans must accept responsibility for preserving biodiversity. (Source: M. Becker, W.J. Christie, J.W. Cowden, J.R. Vallentype, International Association for Great Lakes Research, 1986.)

113: (bus) People can help preserve environmental quality by using public transportation.

114: (cyclists) Bicycling or walking to work or school also helps reduce pollution.

115: (sunset) An ecosystem approach and optimum management are essential to the future well-being of water resources.

Planning Your Program

6.1 Planning Your Global Change Program

Global change, like biological diversity and other critical resource issues, is complex and has a great deal of uncertainty. Those uncertainties and the scientific and educational challenges make the interpretation of the concept of global change exciting. The booklet entitled "Global Change Research in U.S. National Parks" (see Section 3.1) outlines the agency's efforts and the importance of the topic.

Global change is a major research and monitoring element in NPS/NBS science programs. To that end a comparable global climate change communication/ public education/interpretive program targeted to visitors, school children and communities is warranted.

Each park is unique and the Service's resources are diverse; therein lies the value of the National Park System. Each park, using its own themes, goals and objectives as a guide, can address the global change program in a manner deemed most appropriate by that park's staff. No one prescription can be offered to set forth the program each park should follow.

On the other hand, there are commonalities that each park should draw upon. Perhaps foremost is a training plan that ensures all communicators have a sound grasp of the topic, understand the problems associated with misinformation or incomplete information and the uncertainties of global change.

Following the training plan is an action plan that encourages the interpretation of this concept without sounding as an alarmist. Next is the communication plan. The plan begins with a clear understanding of the park's themes, goals and objectives. Specific interpretive objectives can then be constructed as subsets of overall programming objectives. These objectives serve to both direct the programming and provide a basis for evaluation of the programs.

Objectives may then be translated into messages, which are matched with the various media that are in turn matched to target audiences. This matching forms an action plan. In the action plan are listings of allocation of personnel, resources, money and time. Last but not least is an evaluation strategy for the programs themselves.

The inclusion of global change programming should complement, not compete with, existing programming. Given that NPS has divided the nation into 20 biogeographic areas, all with global change research projects relating to most park areas, interpretation of the concept at an appropriate level is warranted.

References

7.1 Glossary

Abiotic Nonliving; referring to the nonliving components of ecosystems (water, light, etc.). (ReVelle and ReVelle, 1988)

Acidification A product of emissions of sulfurous and nitrous oxides that combine with water to produce acids which, when deposited, have detrimental effects on plants and animal communities, particularly in the northern hemisphere where most industrialization has occurred. (Mannion, 1991)

Adaptation A characteristic that helps an organism survive in a particular environment. (ReVelle and ReVelle, 1988)

Atmosphere The envelope of air surrounding the Earth and bound to it by the Earth's gravitational attraction. Studies of the chemical properties, dynamic motions and physical processes of this system constitute the field of meteorology. (U.S Department of Energy, 1990)

Biology The science of life; the study of the principles applied to the origin, structure, function, development and ecology of living organisms as represented by plants, animals and microbes. (Oldfield, 1984)

Biological Diversity The sum of diversity within and between species, between communities and between higher taxonomic levels (family, class, phylum, kingdom); includes genetic diversity. Biological diversity is not necessarily equal to species diversity. Some groups may house more biological (including genetic) diversity than others. (Schonewald-Cox, 1987)

Biomass The total weight of living material, usually expressed in terms of dry weight of an organism, a population or a community. (Oldfield, 1984)

Biomes Climax communities characteristic of given regions of the world. (ReVelle and ReVelle, 1988)

Biota Flora and fauna, considered together. (Oldfield, 1984)

Carrying Capacity The largest population a particular environment can support indefinitely. (ReVelle and ReVelle, 1988)

Carbon Cycle The movement of carbon through the surface, interior and atmosphere of the Earth. The major movement of carbon results from photosynthesis and respiration, with exchange between the biosphere, atmosphere and hydrosphere. The burning of fossil fuels and the release of CO_2 from soil through the clearance of tropical forests may eventually change the balance of the carbon cycle, although the climatic effects may be partly mitigated by the buffering action of the oceans; it is estimated that 200 billion tons of CO_2 have been added to the atmosphere in this way since 1850. (Allaby and Allaby, 1990)
The cycle of carbon in the biosphere, in which plants convert carbon dioxide to organic compounds that are consumed by plants and animals, and the carbon is returned to the biosphere in the form of inorganic compounds by processes of respiration and decay. (Parker, 1984)

Carbon Dioxide A colorless gas made up of two oxygen atoms and one carbon atom, of molecular weight 44.00995, heaviest of the four most abundant gases of dry air. At locations remote from sources of air pollution, CO_2 shows a seasonal variation caused by increased uptake by plants during the growing season, when CO_2 is used in photosynthesis to form carbohydrates in the biosphere. (Hurlbut, 1976)

CO_2 occurs naturally in the atmosphere, and plays an important role in almost all living organisms. Animals, including humans, exhale it while plants take it in, using the carbon it contains to manufacture carbohydrates. There has been a 25 percent increase in CO_2 in the last 100 years. The burning of fossil fuels (coal and oil) and deforestation are the primary contributors of CO_2 from human activity. (Whitimore, 1991)

Carbon Dioxide Fertilization Enhancement of plant growth or of the net primary production by CO_2 enrichment that could occur in natural or agricultural systems as a result of an increase in the atmospheric concentration of CO_2. (U.S. Department of Energy, 1990)

Chlorofluorocarbons (CFC) A family of inert nontoxic and easily liquefied chemicals used in refrigeration, air conditioning, packaging and insulation or as solvents or aerosol propellants. Because they are not destroyed in the lower atmosphere, they drift into the upper atmosphere where their chlorine components destroy ozone. (U.S. Department of Energy, 1990)
CFCs are used as the cooling fluids in refrigeration, as propellants in aerosols, as solvents and as foam-blowing agents in the production of plastics. Unlike the other greenhouse gases, CFCs are not produced naturally and their presence in the atmosphere is due solely to industrial production. Virtually all CFCs produced eventually end up in the atmosphere and are very long-lived. (Whitimore, 1991)

References

7.1 Glossary (con't.)

Climate A complex of atmospheric factors affecting the environment. Climate includes temperature, humidity, amount of precipitation, rate of evaporation, amount of sunlight and winds. (ReVelle and ReVelle, 1988)

Climate Change The long-term fluctuations in temperature, precipitation, wind and all other aspects of the Earth's climate. External processes, such as solar radiance variations, variations of the Earth's orbital parameters (eccentricity, precession and inclination), lithosphere motions and volcanic activity, are factors in climatic variation. Internal variations of the climate system also produce fluctuations of sufficient magnitude and variability to explain observed climate change through the feedback processes interrelating the components of the climate system. (U.S. Department of Energy, 1990)

Climate Variation The change in one or more climatic variables over a specified time. (U.S. Department of Energy, 1990)

Climatic Anomaly The deviation of a particular climatic variable from the mean or normal over a specified time. (U.S. Department of Energy, 1990)

Climax Community The characteristic and relatively stable community for a particular area. (ReVelle and ReVelle, 1988)

Cloud Feedback The coupling between cloudiness and surface air temperature in which a change in surface temperature could lead to a change in clouds, which could then amplify or diminish the initial temperature perturbation. (U.S Department of Energy, 1990)

Community A group of populations that are ecologically and geographically interconnected, and represent a few to several species. Such a group constitutes an assemblage of plants and animals living in a common home, under similar conditions of environment, or with some apparent association of interest. (Schonewald-Cox, 1987)

All of the living creatures, plant and animal, interacting in a particular environment. (ReVelle and ReVelle, 1988)

The biotic components (all organisms considered together) in an ecosystem; an association of interacting populations. (Oldfield, 1984)

Conservation The wise use of natural resources; the planned management of a natural resource to deter or prevent overexploitation, irreversible destruction or neglect. (Oldfield, 1984)

Compromise between protection and multiple land, species and/or resource use. Visitation, concessions, recreation, logging, hunting and mining are various forms of compromise with protection. (Schonewald-Cox, 1987)

Coral Reef A ridge or mass of limestone built up of detrital material deposited around a framework of skeletal remains of mollusks, colonial coral and massive calcareous algae. (Parker, 1984)

Deforestation The removal of forest stands by curing and burning to provide land for agricultural purposes, residential or industrial building sites, roads, etc. or by harvesting the trees for building materials or fuel. Oxidation of organic matter releases CO_2 to the atmosphere and regional and global impacts may result. (U.S. Department of Energy, 1990)

Dendroclimatology The use of tree growth rings as proxy climate indicators. Tree rings record responses to a wider range of climatic variables over a larger part of the Earth than any other type of annually dated proxy record. (U.S. Department of Energy, 1990)

Ecology The study of the interaction between organisms and their environment. (ReVelle and ReVelle, 1988)

Ecologically Important Species A keystone species is one that supports the stability or existence of several to many other species or is biologically important. It is not necessarily a charismatic species but can be. (Schonewald-Cox, 1987)

Ecosystem The organisms of a particular habitat, such as a pond or forest, together with the physical environment in which they live; a dynamic complex of plant and animal communities and their associated nonliving environment. Ecosystems have no fixed boundaries; instead, their parameters are set according to the scientific, management or policy question being examined. Depending upon the purpose of analysis, a single lake, a watershed or an entire region could be an ecosystem. (Reid and Miller, 1989)

Emigration The movement of organisms out of a population. (ReVelle and ReVelle, 1988)

Endangered Species A species that is in danger of extinction throughout all or a significant portion of its range. (U.S. Fish and Wildlife Service, 1994)

References

7.1 Glossary (con't.)

Erosion The loss of soil due to wind or as a result of washing away by water. (ReVelle and ReVelle, 1988)

Evapotranspiration Discharge of water from the Earth's surface to the atmosphere by evaporation from bodies of water, or other surfaces and by transpiration from plants. (U.S. Department of Energy, 1990)

Evolution Change in the frequency of occurrence of various genes in a population. (ReVelle and ReVelle, 1988)

Extinction The cessation of existence for a given form of life. (Schonewald-Cox, 1987)

Extirpation Local extinction (not necessarily by mortality) that includes the driving out of an organism from its habitat by various means, such as by newly introduced competitors or human disturbance. (Schonewald-Cox, 1987)

Feedback Mechanisms A sequence of interactions in which the final interaction influences the original one. (U.S. Department of Energy, 1990)

Food Chain A picture of the relationship between the predators in an area and their prey (i.e. who is eating whom). This term is applied when the relationships are simple and few creatures are involved. (ReVelle and ReVelle, 1988)

Food Web Interconnected food chains made up of many organisms, with many interrelationships. (ReVelle and ReVelle, 1988)

General Circulation Models (GCM) Hydrodynamic models of the atmosphere on a grid or spectral resolution that determine the surface pressure and the vertical distributions of velocity, temperature, density and water vapor as functions of time from the mass conservation and hydrostatic laws, the first law of thermodynamics, Newton's second law of motion, the equation of state and the conservation law for water vapor. Atmospheric general circulation models are abbreviated AGCM, while oceanic general circulation models are abbreviated OGCM. (U.S. Department of Energy, 1990)

Geoengineering Options that may reduce temperature increases by screening sunlight (e.g., space mirrors, stratospheric dust, multiple balloons, stratospheric spot and simulating cloud condensation nuclei) as well as stimulating ocean uptake of CO_2. Considerably more study and research will be necessary to evaluate geoengineering options and potential side effects. (Committee on Science, Engineering and Public Policy, 1991)

Geomorphology The study of present-day landforms, including their classification, description, nature, origin, development and relationship to underlying structures. Also the history of geologic changes as recorded in these surfaces by these surface features. (U.S. Department of Energy, 1990)

Glacier A mass of land ice that is formed by cumulative recrystallization. A glacier flows slowly (at present or in the past) from an accumulation area to an ablation area. (U.S. Department of Energy, 1990)

Greenhouse Effect Atmospheric heating that occurs when outward heat radiation is blocked by greenhouse gases that absorb the energy. The greenhouse effect suggests the Earth will undergo a warming trend as carbon dioxide from fossil fuel combustion accumulates in the atmosphere. (ReVelle and ReVelle, 1988)

Greenhouse Gases Those gases, such as water vapor, carbon dioxide, tropospheric ozone, nitrous oxide and methane, that are transparent to solar radiation but opaque to long-wave radiation. (U.S. Department of Energy, 1990)

Habitat The physical surroundings in which an organism lives. (ReVelle and ReVelle, 1988)

Hydrologic Cycle The process of evaporation, vertical and horizontal transport of vapor, condensation, precipitation and the flow of water from continents to oceans. It is a major factor in determining climate through its influence on surface vegetation, the clouds, snow, ice and soil moisture. (U.S. Department of Energy, 1990)

Hydrology The science dealing with the properties, distribution and circulation of water. (U.S. Department of Energy, 1990)

Immigration The movement of individuals into a population. (ReVelle and ReVelle, 1988)

Migration The periodic movement of organisms into or out of an area. (ReVelle and ReVelle, 1988)

Methane (CH_4) A colorless, odorless, inflammable gas. CH_4 is the principal constituent of natural gas and is also associated with crude oil. (Bates and Jackson, 1980) The major constituent of natural gas; is also produced from many biological decay processes (in the digestive systems

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of ruminant animals such as cattle or deer, and in rice fields and wetlands). Rice production is believed to be the primary contributor of methane from human activity. There has been a 100 percent increase in methane in the past 100 years. (Whitimore, 1991)

Modeling An investigative technique that uses a mathematical or physical representation of a system or theory that accounts for all or some of its known properties. Models are often used to test the effects of changes of system components on the overall performance of the system. (U.S. Department of Energy, 1990)

Natural A term referring to systems unhampered or unmodified by recent humans. No fixed time frame should be set with reference to the word "recent," since characteristics that were adaptive or communities that were natural at an earlier time may no longer be adapted to 20th–21st century conditions. The term "natural" should be used with care, and one's points of reference and values should be specified as one goes along. A more conventional definition (from Webster) might be "in accordance with, or determined by, nature; characteristic of the operations of the physical world; normal. Of, pertaining to or concerned with nature, or the physical universe." (Schonewald-Cox, 1987)

Natural Selection A difference in reproduction whereby organisms having more advantageous genetic characteristics reproduce more successfully than other organisms. This leads to an increased frequency of those favorable genes or gene combinations in the population. (ReVelle and ReVelle, 1988)

Negative Feedback An interaction that reduces or dampens the response of the system in which it is incorporated. (U.S. Department of Energy, 1990)

Niche Where an organism lives and how it functions in this environment (i.e., what it eats, who its predators are, what activities it carries out). (ReVelle and ReVelle, 1988)

Nitrous Oxide (NO_x) A gas produced from microbial action in the soil. Of the nitrous oxide released each year, about 10 percent is due to the use of fertilizer. Natural microbial activity, spread of agriculture, burning of forest vegetation, crop residues and fossil fuels account for most of the rest. (Whitimore, 1991)

Ozone (O_3) A molecule made up of three atoms of oxygen. In the stratosphere, it occurs naturally and it provides a protective layer shielding the Earth from ultraviolet radiation and subsequent harmful health effects on humans and the environment. In the troposphere, it is a chemical oxidant and major component of photochemical smog. (U.S. Department of Energy, 1990)

Photosynthesis The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll with sunlight as the energy source. Oxygen and water vapor are released in the process. Photosynthesis is dependent on favorable temperature and moisture conditions as well as on the atmospheric carbon dioxide concentration. (U.S. Department of Energy, 1990)

Population The organisms, collectively, inhabiting an area or region, as the frog population of a pond. For our purposes, the terms "gene pool" and "population" (of a given species) are synonymous; "population" will be used unless specific reference is made to the genetic properties of a group of interbreeding individuals. (Schonewald-Cox, 1987)

Positive Feedback An interaction that amplifies the response of the system in which it is incorporated. (U.S. Department of Energy, 1990)

Precipitation Any or all forms of liquid or solid water particles that fall from the atmosphere and reach the Earth's surface. It includes drizzle, rain, snow, snow pellets, snow grains, ice crystals, ice pellets and hail. Precipitation is also defined as a measure of the quantity, expressed in centimeters or milliliters of liquid water depth, of the water substance that has fallen at a given location in a specified amount of time. (U.S. Department of Energy, 1990)

Preservation Protection of biological diversity without intentional compromises; it includes protection of parts and processes. Preservation suggests the act of preventing injury, destruction or decay; maintaining a state of preservation; or assuring the existence or intactness of biological diversity. (Schonewald-Cox, 1987)

Radiation Any form of emitted wave phenomena usually the electromagnetic spectrum, sound or heat. (Allaby and Allaby, 1990)

Radiation Balance The difference between the absorbed solar radiation and the net infrared radiation. Experimental data show that radiation from the Earth's natural surfaces is rather close to the radiation from a black body at the corresponding temperature; the ratio of the observed values of radiation to black body radiation is generally 0.90–1.0. (U.S. Department of Energy, 1990)

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7.1 Glossary (con't.)

Relative Sea Level The height of the boundary between sea and air as measured in relationship to a fixed reference point on land. (U.S. Department of Energy, 1990)

Respiration A biochemical process by which living organisms take up oxygen from the environment and consume organic matter, releasing both carbon dioxide and heat. (U.S. Department of Energy, 1990)

Species All those organisms that are able to interbreed successfully (if they are given the opportunity to do so), that share ties of common parentage and share a common pool of hereditary material. (ReVelle and ReVelle, 1988)

Species One or more populations of individuals that are reproductively compatible and comprise a distinct form of animal or plant. Noteworthy exceptions are not the object of discussion here. This simpler definition is thought to be sufficient for this report, although for reference purposes, Webster defines "species" as "a category of classification lower than a genus or subgenus and above a subspecies or variety; or as a group of animals or plants that possess one or more characters distinguishing them from other similar groups, and do or may interbreed and reproduce their characters in their offspring, exhibiting between each other only minor differences bridged over by intermediate forms and differences ascribable to age, sex, polymorphism, individual peculiarity or accident, or selective breeding by man." (Schonewald-Cox, 1987)

Stratosphere The region of the upper atmosphere extending from the tropopause (8 to 15 km altitude) to about 50 km. (U.S. Department of Energy, 1990)

Threatened Species A species that is not yet endangered but whose populations are heading in that direction. (ReVelle and ReVelle, 1988)

Transpiration Annual growth increments of trees that indicate, among other factors, the climatic conditions that enhance or limit growth. (U.S. Department of Energy, 1990)

Troposphere The inner layer of the atmosphere below about 15 km, within which there is normally a steady decrease of temperature with increasing altitude. (U.S. Department of Energy, 1990)

Upwelling The vertical motion of water in the ocean by which subsurface water of lower temperature and greater density moves toward the surface of the ocean. Upwelling occurs most commonly along the western coastlines of continents, but may occur anywhere in the ocean. Upwelling results when winds blowing nearly parallel to a continental coastline transport the light surface water away from the coast. Subsurface water of greater density and lower temperature replaces the surface water, and exerts a considerable influence on the water of coastal regions. Carbon dioxide is transferred to the atmosphere in regions of upwelling. (U.S. Department of Energy, 1990)

Weather The instantaneous state of the global atmosphere ocean-cryosphere system. (U.S. Department of Energy, 1990)

Wetland An area that is regularly saturated by surface water or groundwater and subsequently is characterized by a prevalence of vegetation that is adapted for life in saturated soil conditions. (U.S. Department of Energy, 1990)

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Films and Videos
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Video entitled *The Global Brain*
Produced on VHS or Beta
This video presents Peter Russell's version of humanity's potential. He outlines the possibilities for humanity to use its combined intelligence in a positive way as a "global brain."

Films for the Humanities and Sciences**, 1994
Video entitled *Climate Out of Control*
Produced on VHS
This program examines the impact of global warming on New England.

Films for the Humanities and Sciences**, 1994
Video entitled *The Heat is On: The Effects of Global Warming*
Produced on VHS
Scientists explain the effects of global warming: a rise in extreme weather systems, droughts, floods, forest fires, the disappearance of animal species, the movement of forests northward and epidemics resulting from climatic change.

Films for the Humanities and Sciences**, 1994
Video entitled *Race Against Tomorrow*
(drama)
Produced on VHS
A young boy thinks environmental concerns are a lot of nonsense. He can't be bothered with saving water or energy — until he gets a glimpse of the future and sees what life might become, with deserted towns, undrinkable water and unbreathable air.

Films for the Humanities and Sciences**, 1994
Video entitled *The Greenhouse Effect*
Produced on VHS
This program analyzes the sun's gradual brightening and the relationship between sunlight and CO_2, explains why the atmosphere of Mars has too little and Venus too much CO_2 to sustain life, theorizes about the disappearance of dinosaurs and a dinosaur-friendly climate and explains the relationship between climatic change and continental drift.

Films for the Humanities and Sciences**, 1994
Video entitled *Sun, Sunlight and Weather Patterns*
Produced on VHS
This program explains the origin of tropical storms, tropical rainforests and polar deserts. It shows the route and the effect of the Gulf Stream and its role in the Little Ice Age of the 16th century. Also examined are the causes of the formation of the Sahara Desert, changes in the sun's activity and the cycles involving dust storms and volcanic eruptions.

Films for the Humanities and Sciences**, 1994
Video entitled *Civilization and Climate*
Produced on VHS
Links between climatic changes and emerging civilizations have been postulated and the collapse of civilizations confronted with climatic challenges to which they could not adapt is documented.

Films for the Humanities and Sciences**, 1994
Video entitled *Modifying the Weather: The Case of the Man-made Desert*
Produced on VHS
Documents migration in the Sahel, water usage policy in Arizona and efforts to irrigate the desert in Central Asia. The program details these events and shows the consequences for the population, the physical geography and the climate.

Films for the Humanities and Sciences**, 1994
Video entitled *Global Warming*
Produced on VHS
Observation, historical records and computer models indicate that temperatures are rising. Low-lying areas will eventually be under water, diseases and predators will proliferate, rainfall will increase in some parts of the world, while elsewhere drought will strike and mass starvation will occur.

Films for the Humanities and Sciences**, 1994
Video entitled *Danger Ahead: Is There No Way Out?*
Produced on VHS
Suggests some solutions to the threat of global warming, but states that greenhouse gases are produced by fundamental biological processes and there is no reasonable way to stop their proliferation.

Films for the Humanities and Sciences**, 1994
Video entitled *Drought and Flood: Two Faces of One Coin*
Produced on VHS
The predicted effects of global warming may appear to be paradoxical, but they are actually completely logical — and devastating.

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Video entitled *After the Warming*

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Selected papers, activities and resources
Available from New Mexico State Univ., Dept. 3AP, Box 30001, Las Cruces, NM 88003-0001

National Wildlife Federation*, 1988
Video entitled *Our Threatened Heritage*
Produced on VHS or Beta
This video provides an overview of the destruction of the rainforests and what can be done to stop it.

Richard Somerville, Scripps Institution of Oceanography
Video entitled *Should We Believe Climate Prediction?*
Distributed by Aspen Global Change Institute, Aspen, CO

Students of Oak Meadow School*, 1989
Video entitled *We Can Make a Difference*
Produced on VHS
This video presents 12 high school students concerned about the environment who decide to inspire other young people to save the planet.

Union of Concerned Scientists*, 1989
Video entitled *Greenhouse Crisis — The American Response*
Produced on VHS
This fast-paced video illustrates the relationship between energy consumption, the greenhouse effect and global warming.

WGBH Foundation, 1990
Video entitled *"Only One Atmosphere" Race to Save the Planet*
This program examines the consequences of an altered climate and its impact on different aspects of human life. Approximately 25 minutes into the program it deals with the consequences of sea level rise and examines how one country has combated this problem in the past.

WorldLink
Video entitled *Spaceship Earth: Our Global Environment*
Available from:
WorldLink
PO Box 4804893
Los Angeles, CA 90048
213/273-2636

* These videos are available through:
The Video Project
5332 College Ave., Suite 101
Oakland, CA 94618

**These videos are available through:
Films for the Humanities and Sciences
PO Box 2053
Princeton, NJ 08543-2053
800/257-5126

Slides

See Section 5.10 for captioned slide source.

Climate Protection Institute
5833 Balmoral Dr.
Oakland, CA 94619
HyperCard information retrieval program on global climate change. It gives information about trees and global climate change.

Miscellaneous

Air Pollution Control Association
PO Box 2861
Pittsburgh, PA 15230
Publishes *Journal of the Air Pollution Control Association*

American Forestry Association
1319 18th St. NW
Washington, DC 20036
Publishes *American Forests*
Concerns: soil and forest conservation, reforestation, creation of parks and trees' role in fighting pollution.

American Geological Institute
4220 King St.
Alexandria, VA 22302-1507
Publishes *Earth Science Education Connection*

Bureau of National Affairs, Inc., The
1231 25th St. NW
Washington, DC 20037
800/372-1033
Publishes *World Climate Change Report*

Canadian Global Change Program
The Royal Society of Canage
PO Box 9734
Ottawa, Ontario K1G 5J4
Publishes newsletter entitled *Delta*

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CDIAC (Carbon Dioxide Information Analysis Center)
Communications
Oak Ridge National Laboratory
MS-6335: Bldg. 1000
PO Box 2008
Oak Ridge, TN 37831-6336
Publishes *Communications*
Provides education materials from the U.S. government; many are too technically advanced for primary grades.

Center for Action on Endangered Species
175 W. Main St.
Ayer, MD 01432

Center for Environmental Information
33 S. Washington St.
Rochester, NY 14608
716/546-3796

Climate Institute, The
316 Pennsylvania Ave. SE, Suite 403
Washington, DC 20003
202/547-0104
Publishes *Global and Planetary Change Newsletter* and *Climate Alert Newsletter.*

Climate Protection Institute
5833 Balmoral Dr.
Oakland, CA 94619
Publishes a newsletter entitled *Greenhouse Gas-Ette* on global change education and a 3-diskette set of "Knowledge Tree on Global Climate Change."

Conservation and Renewable Energy Inquiry and Referral Service
PO Box 8900
Silver Spring, MD 20907
Provides conservation and renewable energy information.

Consumer Information Center-K
PO Box 100
Pueblo, CO 81002
Provides a catalog of pamphlets (some at no charge). Pamphlets are government-produced for consumers on various subjects including endangered species and national parks.

Earth Day 90
PO Box AA
Stanford, CA 94309

Earthscan
1717 Massachusetts Ave. NW
Washington, DC 20036
Publishes *Conservation Foundation Letter*, a newsletter summarizing major environmental issues.

Environmental Defense Fund
257 Park Ave. S.
New York, NY 10010
212/505-2100

Elsevier Science Publishing Co., Inc.
655 Avenue of the Americas
New York, NY 10010
Global Climate Change Digest provides publication sources, reports, news and calendar. The publication's aim is to provide for access to technical and general information on climate change, particularly as induced by humans.

Global Tomorrow Coalition
13325 G St. NW, Suite 915
Washington, DC 20005
Publishes *Interaction*

Heldref Publications
4000 Albemarle St. NW
Washington, DC 20016
Publishes *Environment*
Contains articles with details on environmental issues.

International Cultural Foundation
GPO Box 1311
New York, NY 10116.

Office of Interdisciplinary Earth Studies
Universities Corporation for Atmospheric Research
PO Box 3000
Boulder, CO 80307-3000
Publishes *Earthquest*

NASA Goddard Institute for Space Studies
2880 Broadway, Rm 750
New York, NY 10025
212/678-5619, 678-5500

National Science Foundation
1800 G St. NW, Rm. 527
Washington, DC 20550
Publishes *Mosaic*, an account of current research which the NSF is concerned, *National Science* and *Technology Week.*

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Natural Resources Defense Council
1350 New York Ave. NW
Washington, DC 20006
202/783-7800

Ohio State University
059 Ramseyer Hall
29 W. Woodruff Ave.
Columbus, OH 43210
Publishes a newsletter of the program for leadership in Earth Systems Education.

Population Reference Bureau, Inc.
2213 M St. NW
Washington, DC 20002
Publishes *Population Bulletin*, a newsletter of readable documentation regarding world population, educational aids and slide show presentation material.

Public Information Center (PM-211B)
U.S. Environmental Protection Agency
Waterside Mall, Garage Level
401 M St.
Washington, DC 20460
202/382-2080
Distributes a variety of nontechnical information about the environment to private citizens, academic institutions, civic and environmental organizations

Rocky Mountain Institute Newsletter
Snowmass, CO 81654-9119
Fall 1989 (Vol. 5. No. 3)

Sierra Club
730 Polk St.
San Francisco, CA 94109
415/776-2211

Solar Lobby
1001 Connecticut Ave. NW, Suite 638
Washington, DC 20036
Lobbies for solar energy use/development and additional renewable energy sources.

Union of Concerned Scientists
26 Church St.
Cambridge, MA 02238
617/547-5552
A nonprofit organization of approximately 100,000 scientists and others concerned about the impact of advanced technology on society. UCS conducts programs on national energy policy, national security policy and nuclear power safety.

United Nations Publications Catalog
Sales Selection
Room DC 2-853, Dept. 701
New York, NY 10017
Publishes a catalog with not only environmental topics but also other world problem topics.

World Resources Institute
1735 New York Ave. NW
Washington, DC 20006
202/638-6300

Worldwatch Institute
1776 Massachusetts Ave. NW
Washington, DC 20036
Focuses on worldwide environmental affairs and provides an annual *State of the World Report*, a magazine on environmental affairs and various other pamphlets.

World Wildlife Fund
1250 24th St. NW
Washington, DC 20037
202/293-4800

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