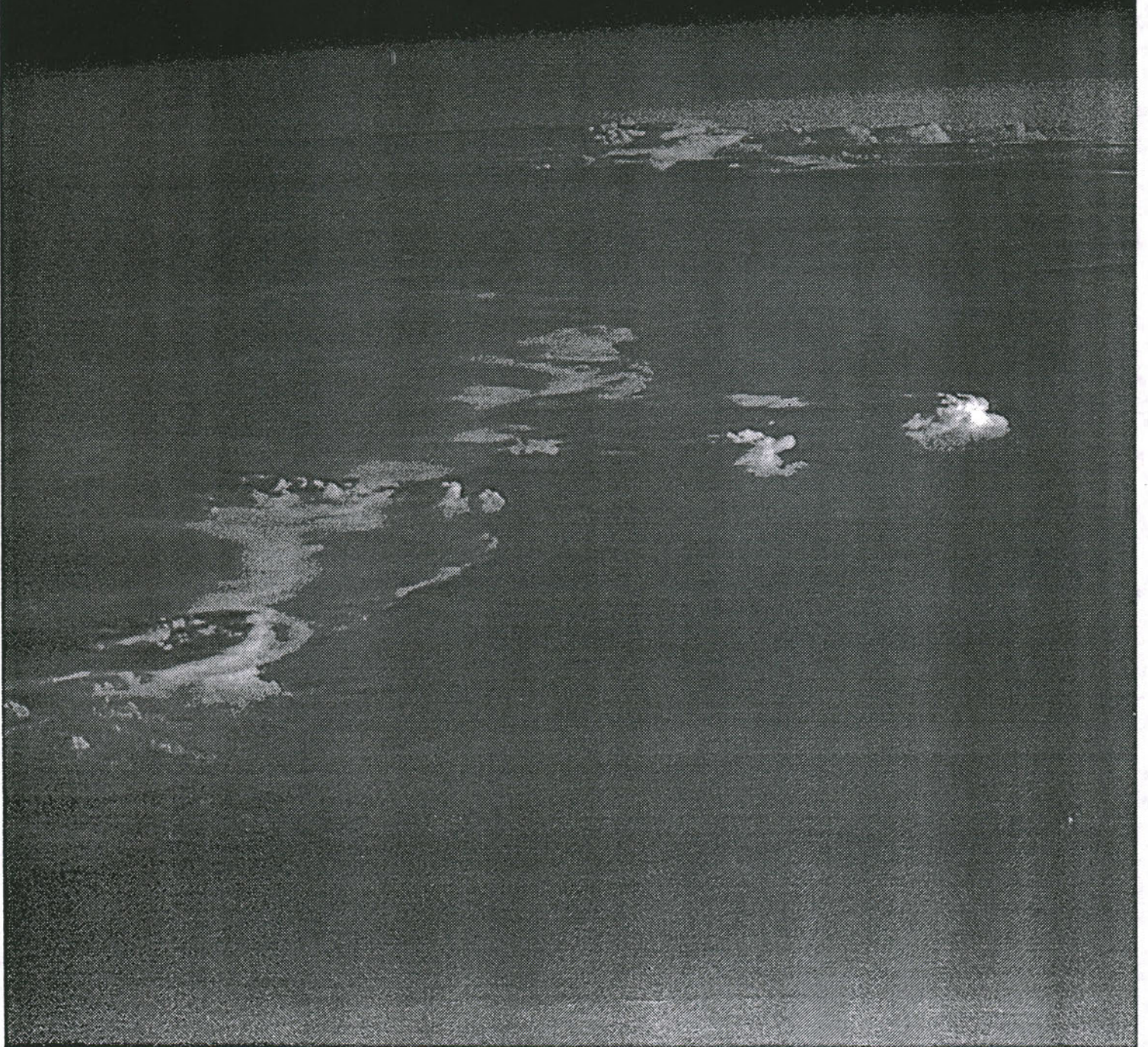


CLIMATE CHANGE

What We Know



CLIMATE CHANGE

What We Know



- make smaller, move to inside front cover, accompanied by following sentences:

- .. The Office of Science and Technology Policy was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP^{is} responsible^{for} ~~for~~ advising the President on all questions in which science and technology are important elements, including climate change.

Background

During the 1980s, scientific evidence about global climate change and its consequences led to growing concern among scientists, policy makers, and the public. In 1988, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) jointly established the Intergovernmental Panel on Climate Change (IPCC). Through the IPCC process, scientists representing more than 150 countries have assessed the available information on climate change and its environmental and economic effects and have provided the scientific understanding needed to help formulate appropriate responses. A series of IPCC reports, incorporating extensive peer review and a commitment to scientific excellence, have provided the most authoritative and comprehensive information available on the science of climate change. In 1996, the IPCC published its Second Assessment Report, which summarizes the most recent information on climate change science and the vulnerability of natural and socioeconomic systems.

IPCC Website: <http://www.ipcc.ch/>

In 1990, the United Nations General Assembly established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (FCCC). Negotiators from over 150 nations drafted the FCCC, which was adopted on May 9, 1992, at UN Headquarters. The ultimate aim of the FCCC is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system." This stabilization should be achieved within a time frame that (1) allows ecosystems to adapt naturally to climate change, (2) ensures that food production is not threatened, and (3) enables sustainable economic development to proceed.

Framework Convention Website:
<http://www.unep.ch/uicc.html>

In the United States, climate change research is overseen by the U.S. Global Change Research Program (USGCRP), which was established in 1989. Since its inception, the USGCRP has strengthened research on key scientific issues and has fostered improved understanding of Earth processes. New directions for the USGCRP include identifying and analyzing regional vulnerabilities to climate variability and climate change. The results of the research it supports have played an important role in the work of the IPCC and other national and international bodies.

GCRP Website: <http://www.usgcrp.gov/>

Fix as appropriate, given
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This publication has been prepared by the Office of Science and Technology Policy (OSTP). The OSTP was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976. OSTP's responsibilities include advising the President on policy formulation and budget development on all questions in which science and technology are important elements; articulating the President's science and technology policies and program; and fostering strong partnerships among Federal, State, and local governments, and the scientific communities in industry and academia.

To obtain additional information contact the OSTP Administrative Office at 202-456-6004.

...the greenhouse
...the atmosphere
...the climate
...the weather

AGE
Comparison

Introduction

A ...

Burning coal, oil and natural gas to heat our homes, power our cars, and illuminate our cities produces carbon dioxide (CO₂) and other greenhouse gases as by-products. In recent decades, atmospheric levels of CO₂ and other greenhouse gases have climbed steadily, and are projected to continue their steep ascent.

that there is "a discernible human influence on global climate." The IPCC also estimated ~~that an increase in~~ global surface air temperature of about 3.5°F is likely by the year 2100, although the change could be as low as 2°F and as high as 6.5°F. This represents a faster rate of climate change than at any time during the last 10,000 years, the period in which modern civilization developed.

BETWEEN
2-6.5°F
BEST GUESS OF
3-5°F

EVEN AT THE
LOWEST ESTIMATE
OF 2°F, THAT
WOULD

Computerized simulations of climate and records of past climate going as far back as 160,000 years indicate that the composition of the atmosphere and global temperature are tightly linked. As atmospheric concentrations of CO₂ increase, global temperatures rise. The Intergovernmental Panel on Climate Change (IPCC) has concluded that Earth has already warmed about 1 °F over the last century. ~~Further modification of the atmosphere is expected to result in further warming of the Earth's surface.~~ In 1996, the IPCC stated for the first time that the balance of the scientific evidence now suggests

precipitation

Warming of this magnitude will affect many aspects of our lives, in complicated ways. Our health, the vitality of forests and other natural areas, and the productivity of agriculture will all be affected by the resulting changes in temperature, weather, sea level, and fresh water supply. As the risks of global climate change become increasingly apparent, there is an urgent need to focus on actions to slow atmospheric change and minimize the adverse impacts of a changing climate.

AS IT WOULD
TEMPERATURE
PARTS, IN THE
SEA LEVEL RISE
AND CONSIDER
FRESH WATER
SUPPLY
THE CLIMATE
ON ...

DECREASE THE GREENHOUSE
THE EFFECTS

Continued
addition
of greenhouse
gases will
result in

CONCLUSION

Even if it were possible to eliminate greenhouse gas emissions ^{today}, temperatures would continue rising for decades.

...THE WARMING TENDS TO
...INTENSIFY AS MORE GREENHOUSE GASES
...INTO THE ATMOSPHERE

ALL THE
LIKELY
TO BE
...WARMING

SIGNIFICANTLY INCREASED
THE AMOUNT OF GREENHOUSE
GASES IN THE ATMOSPHERE.

The Greenhouse Effect and Historical Emissions

Life as we know it is possible on Earth because of a natural greenhouse effect that keeps our planet about 60 °F warmer than it otherwise would be (Figure 1). Water vapor, carbon dioxide (CO₂), and other trace gases, such as methane and nitrous oxide, trap solar heat and keep it from being lost by re-radiation back to slow its loss

space. With industrialization and population growth, the amounts of greenhouse gases added to the atmosphere by human activities have grown to significant proportions, and these steady additions have begun to tip a delicate balance. In the United States, carbon emissions per person now exceed 5 tons per year, about 5 times the global average.

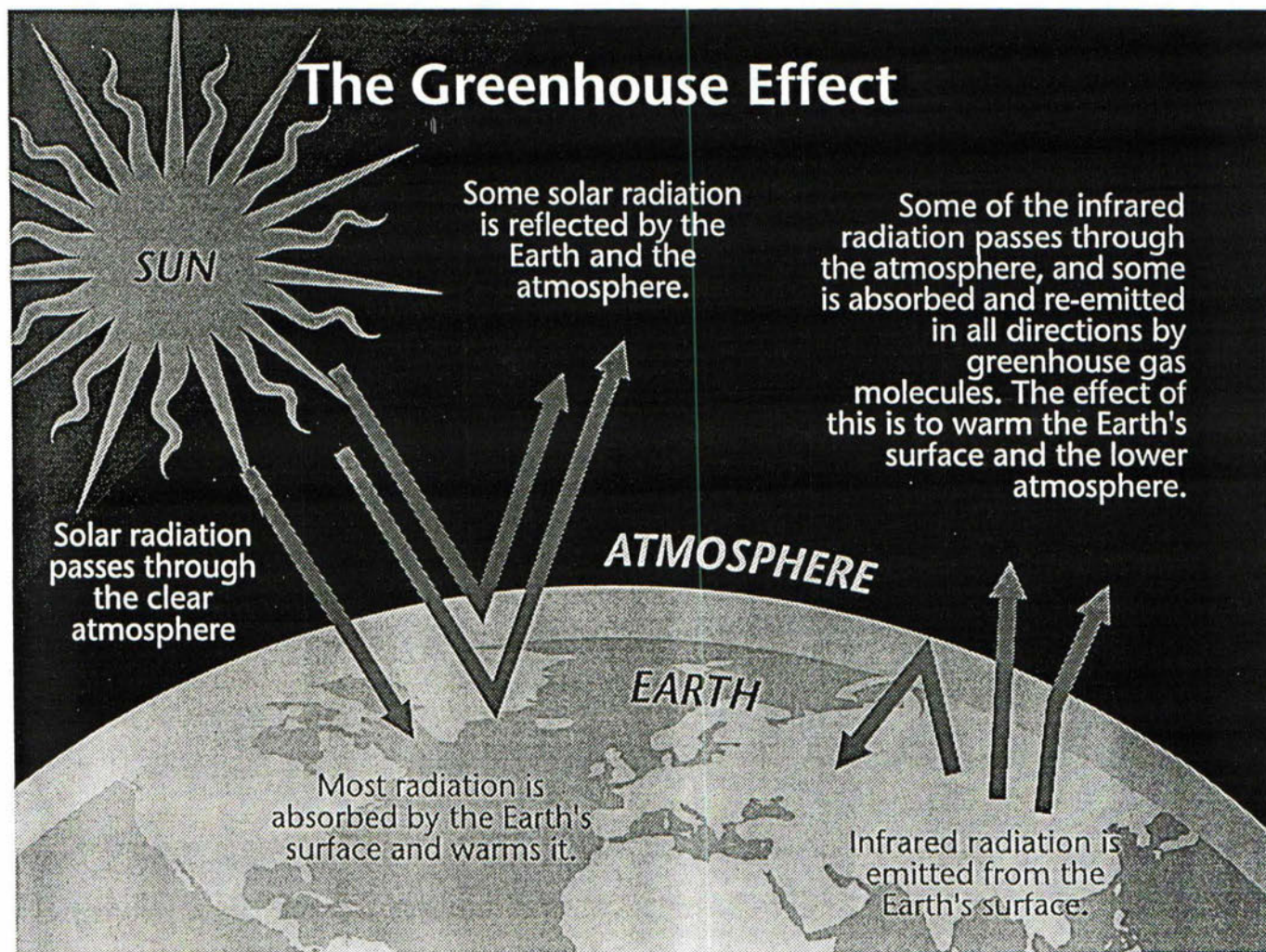


Figure 1. The greenhouse effect naturally warms Earth's surface. Without it, Earth would be 60 °F cooler than it is today – uninhabitable for life as we know it.

the

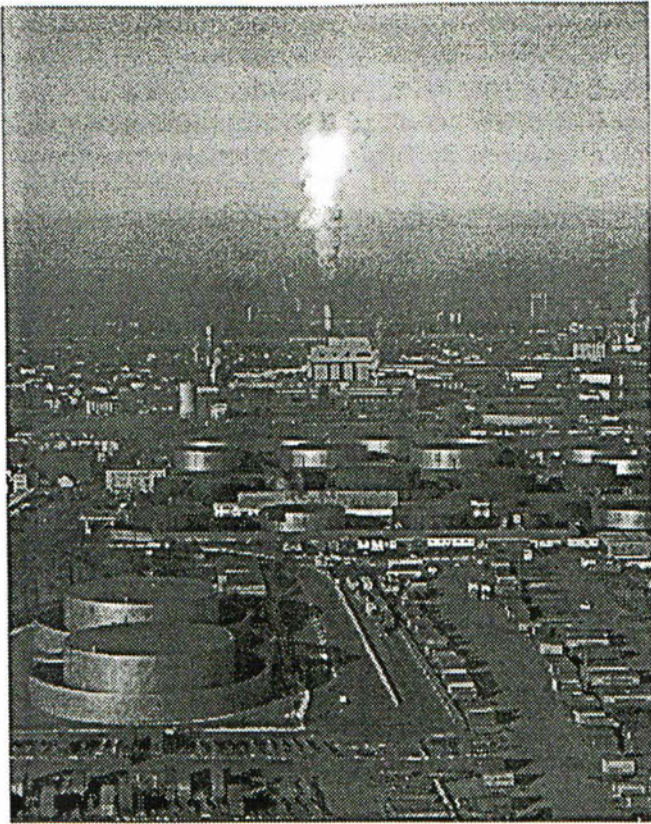


Figure 2. Burning fossil fuels such as coal, oil, and gas, add 6 billion metric tons of carbon each year into the atmosphere.

world wide

The average American household produces 2.5 tons of carbon emissions each year just by driving the family cars. On a global scale, burning of coal, oil, and natural gas releases about 6 billion tons of carbon into the atmosphere each year. With the global population of about 6 billion people, the average per person emissions are about 1 ton of carbon per year. Land-use change, predominantly the clearing of forests for agriculture, contributes another 1-2 billion tons annually by reducing the uptake and storage of carbon by trees (Figures 2 and 3). Consequently, greenhouse gas concentrations in the atmosphere are now rapidly increasing.

Burnin
und logg.



Figure 3. Deforestation worldwide adds 1 to 2 billion metric tons of carbon to the atmosphere each year.

Handwritten notes at top left: "CO2 concentration has increased 30% since 1860", "Methane concentration has more than doubled", "Nitrous oxide has risen by 15 percent".

Agricultural and industrial practices have also doubled the concentration of methane in the atmosphere and increased nitrous oxide levels by about 15 percent.

Consequently, overall greenhouse gas concentrations in the atmosphere are rapidly increasing.

Handwritten note at top right: "the atmospheric level of".

Since 1860, CO₂, the most important human-derived greenhouse gas, has increased 30 percent, from 280 to 360 parts per million (ppm) (Figure 4). Methane concentration has more than doubled. Nitrous oxide has risen by 15 percent.

Handwritten note: "HISTORICAL RECORDS INDICATE A".

For millennia, there has been a clear correspondence between CO₂ levels and the global temperature record. Fluctuations of CO₂ and temperature have closely mirrored each other over the last 160,000 years (Figure 5).

Handwritten note: "FOR AS LONG AS RELIABLE RECORDS".

Carbon Dioxide Concentrations

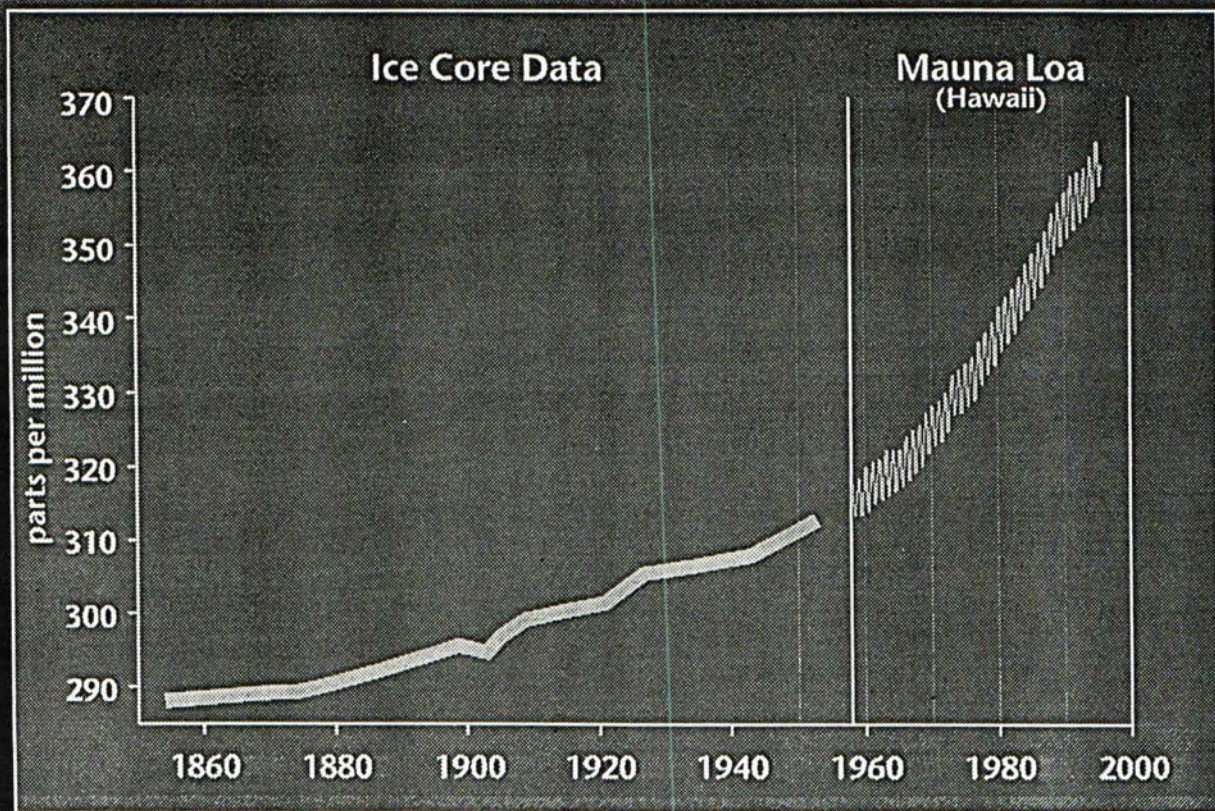


Figure 4. Since the beginning of the Industrial Revolution in the middle of the 19th century, the concentration of carbon dioxide (CO₂) in the atmosphere has steadily increased. Beginning in 1957, continual observations from Mauna Loa, Hawaii show the seasonal cycle of vegetation northern latitudes: each spring the vegetation "inhales" and absorbs CO₂, and each autumn part of that CO₂ is released back to the atmosphere.

Atmospheric Carbon Dioxide Concentration and Temperature Change

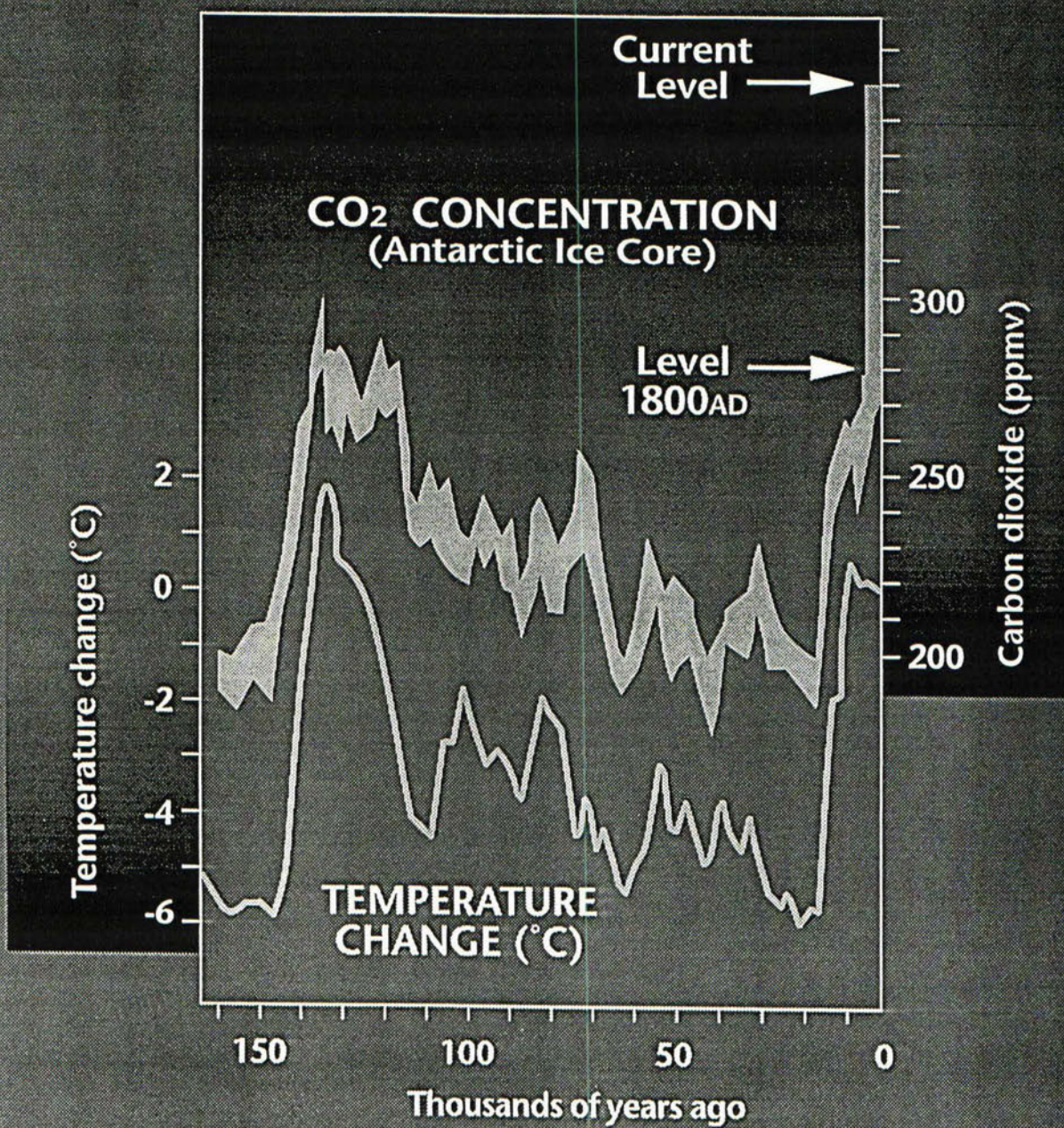


Figure 5. Data collected from tiny bubbles trapped in ice cores indicate that over the last 160,000 years the atmospheric CO₂ concentration and the temperature record have mirrored each other.

1990

Which countries account for the largest proportions of CO₂ emissions? In 1990, 74 percent of the total CO₂ emissions from human activities came from the developed countries, with the United States the largest single source (accounting for 22 percent of the total) (Figure 6). Over the next few decades, 90 percent of the world's population growth will take place in the developing countries, some of which are

undergoing rapid economic development. Per capita energy use in the developing countries, which is currently only 1/10 to 1/20 of the U.S. level, will also increase. If current trends continue, the developing countries will account for more than half of total global carbon emissions by 2035. By that time, China, which is currently the second largest source, is likely to displace the United States as the largest emitter.

Fix chart to be 1995/2035 expected before then

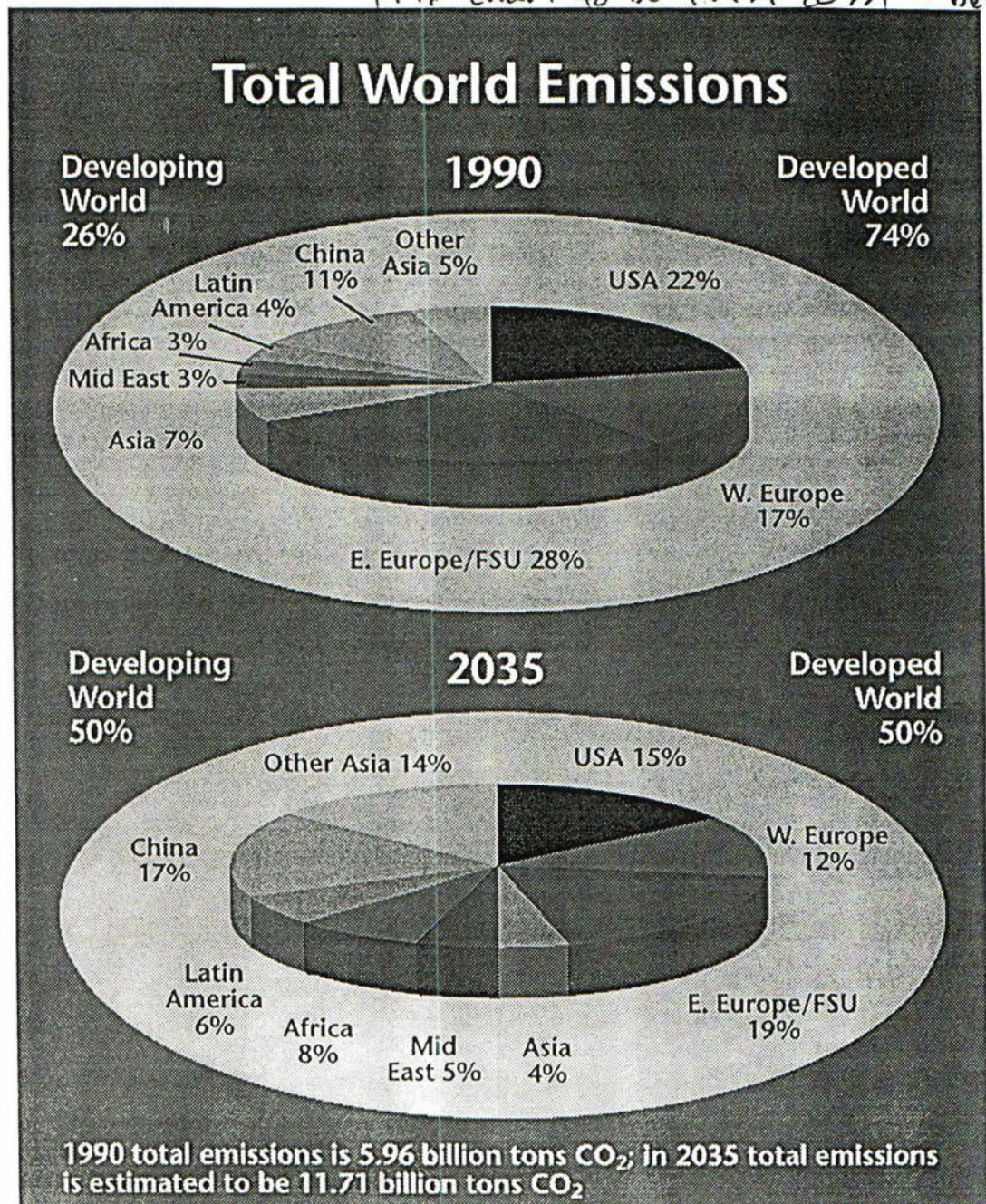


Figure 6. In 1990, the industrialized developed nations of the world contributed nearly three-quarters of the global emissions of carbon dioxide, with the U.S. being the largest single emitter. By 2035, developing nations will catch up and contribute half of the global emissions, with China becoming the largest single emitting country. Rapid population growth, increasing consumption per person, and industrialization will contribute to this shift.

Climate Change Over the Last 100 Years

How has the climate changed to date? The IPCC's Second Assessment Report (1996) described a series of changes that already have been observed. Global surface temperature has been measured since 1880 at a network of ground-based and ocean-based sites. Over the last century, the average surface temperature of the Earth has increased by about 1.0 °F to a level ~~that is~~ as high or higher than it has been in any century since at least 1400 AD. The eleven warmest years this century have all occurred since 1980, with 1995 the warmest on record (Figure 7). The higher latitudes already have warmed even more.

Beginning in 1979, satellites ~~also~~ have been used to measure the temperature of the atmos-

Satellite observations were initially interpreted as showing a slight cooling, but more recent

phere up to a height of 30,000 feet. The long-term surface temperature record and the short-term satellite observations ~~of the atmosphere~~ differ, but the fact that the two records are not identical is not surprising. The two techniques measure different aspects of global temperature, and both are influenced by a variety of factors, such as the presence of airborne materials from the 1991 eruption of the volcano Mt. Pinatubo.

~~Recent~~ analyses have identified warming in the satellite record just as the ground-based measurements have indicated over a longer time period. As more data from the satellite record become available, and as the quality of measurements is improved, comparison of these two records is likely to yield additional insights.

accounting for natural, short-term fluctuations

Global Average Temperature

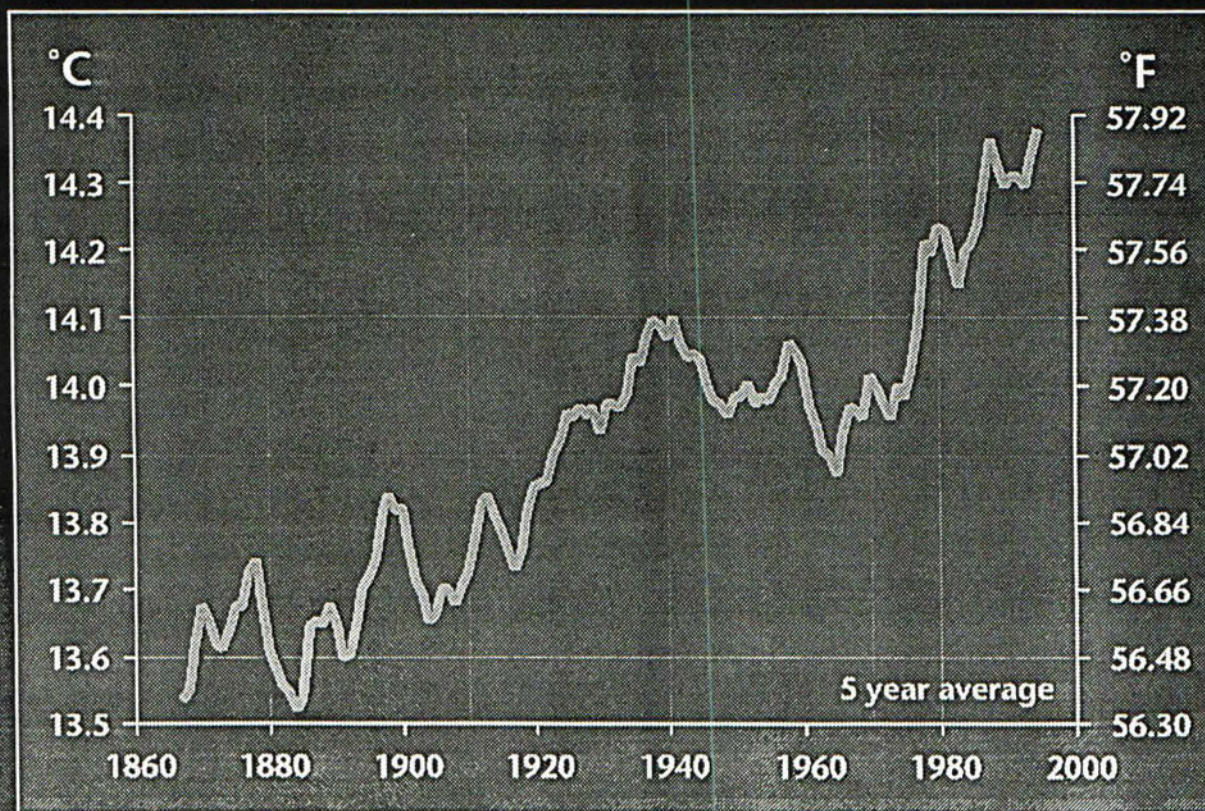


Figure 7. The global average temperature has risen by approximately 0.5 °F to 1 °F over the last century.

Higher temperatures will cause

What does warming do? A warmer Earth speeds up the global water cycle: the exchange of water among the oceans, atmosphere, and land. ~~Because there is more evaporation at and higher temperatures, soils tend to dry out faster. Because there is more water in the atmosphere, there is also more rain or snow overall.~~

It will mean

We may be seeing the first signs of changes in the water cycle. Since the beginning of the century, precipitation in the United States has increased by about 6 percent, with about a 20 percent increase in the frequency of intense precipitation events such as heavy downpours. ~~Such events have led to flooding, soil erosion, and loss of life (Figure 8 and 9). But in~~ some midcontinental areas, increased evaporation has led to drought because the heavy rains fell elsewhere.

There is also evidence that ecosystems are responding to warming. Between 1981 and 1991, the length of the growing season in the northern high latitudes (between 45° and 70° N) increased by a total of up to twelve days, as documented by satellite imagery. "Greening" in spring and summer occurred up to eight days earlier, and vegetation continued to photosynthesize an estimated four days longer.

Sea level is also rising, mainly because the oceans, like all water, expand when heated. The melting of ice caps and glaciers is also contributing to this effect. ~~Over the last century, global mean sea level has risen 4 to 10 inches. During this time, mountain glaciers have retreated worldwide.~~ Formerly frozen soils (permafrost) in the Alaskan arctic have begun to melt, damaging both ecosystems and infrastructure. Melting and tundra warming will also lead to decay of organic matter and the release of trapped carbon and methane, creating an additional source of greenhouse gases.

which has occurred worldwide over the last century,

over this period of time

More than 2 inches per day.

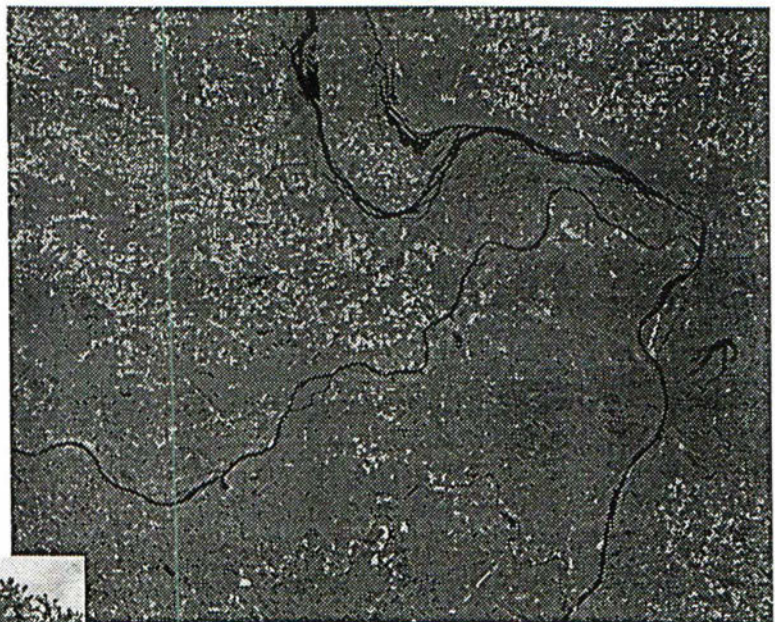


Figure 8 and 9. Our society is already vulnerable to extreme weather events such as floods. During floods as severe as the 1993-Mississippi-River flood, communities and cities like St. Louis, Missouri will face massive destruction as the riverbanks overflow.

8 These images show the devastating effects of the 1993 Mississippi River flood. The flood was the worst in the history of the United States.

Climate Change Over the Next 100 Years

and much more than double the pre-industrial level of ~280 ppm.

Where is the climate headed? If the world proceeds on a "business as usual" path, atmospheric CO₂ concentrations will likely be more than 700 ppm by 2100, nearly double the current level of 360 ppm (Figure 10). State-of-the-art climate models suggest that this will result in a 2 °F to 6 °F increase in global temperatures over the next century. This is a rate of climate change not seen on the planet for at least the last 10,000 years.

Furthermore, even if atmospheric CO₂ were stabilized at 700 ppm by the year 2100, it would likely take several more centuries for temperature to stabilize and the sea level to stop rising.

What are the projected extent and pattern of warming over the globe? The higher latitude regions will warm more than areas nearer to the equator. The land surface will warm more than the oceans and there will be less variation in temperature from night to day. The United States would eventually stabilize at a temperature 5.5 °F to 12 °F warmer than at present -- that

Atmospheric Carbon Dioxide Concentration and Temperature Change

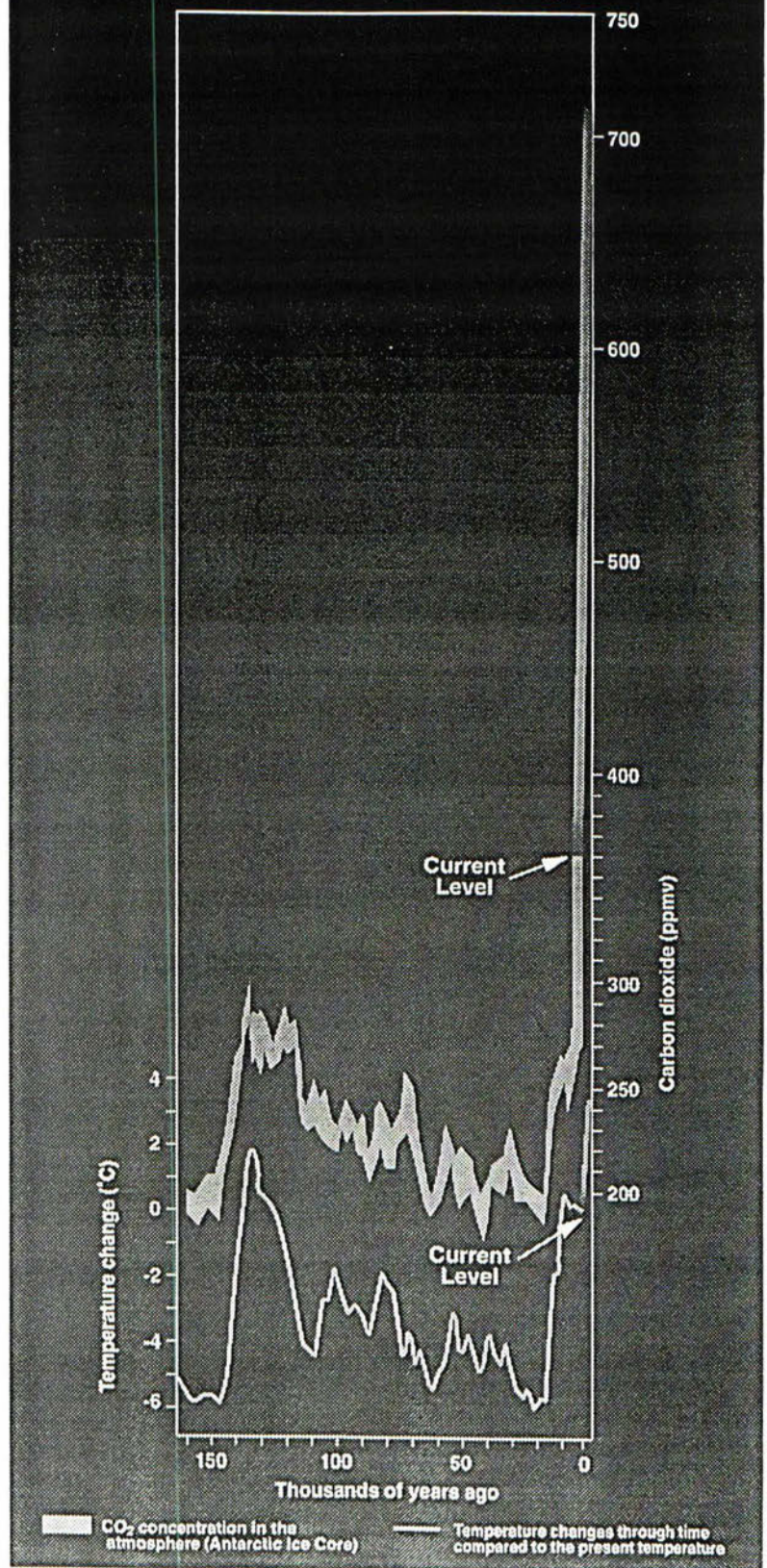


Figure 10. The CO₂ level has already increased sharply since the beginning of the Industrial Era. Compared to the relatively small window of fluctuations over the past 160,000 years, the projected future CO₂ levels over the coming 100 years shoot virtually straight up to 700 ppm. This is expected to cause a warming of 2 °F to 6 °F by the year 2100.

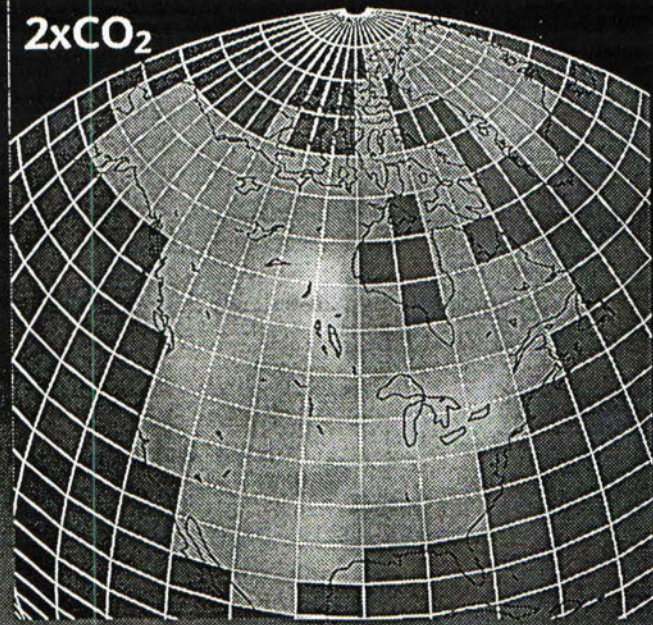
and is already outside the bounds of natural variability of current levels of emissions with

is, any particular month would be that much warmer (Figure 11). Even if the rate of emissions is slowed enough to limit atmospheric concentrations to about 560 ppm, or about double the pre-industrial level, the U.S. is likely to experience temperature increases of 5-10°F. These warmer temperatures would lead to soil drying in some regions, with drying estimated at 10 percent to 30 percent for the United

Figure 12. The extent of warming indicated in Figure 11 will lead to substantial soil drying throughout the world, reaching soil moisture decreases of 10 percent to 30 percent over North America.

Percent Reduction in June-August Soil Moisture

2xCO₂



0 10 20 30 40 50 60

Figure 11. Even if CO₂ levels only rise to 560 ppm by the year 2100, our climate will eventually stabilize at temperatures 5°F to 10°F warmer than today. The projected warming will not be uniform around the globe.

Surface Air Warming (°F)

2xCO₂

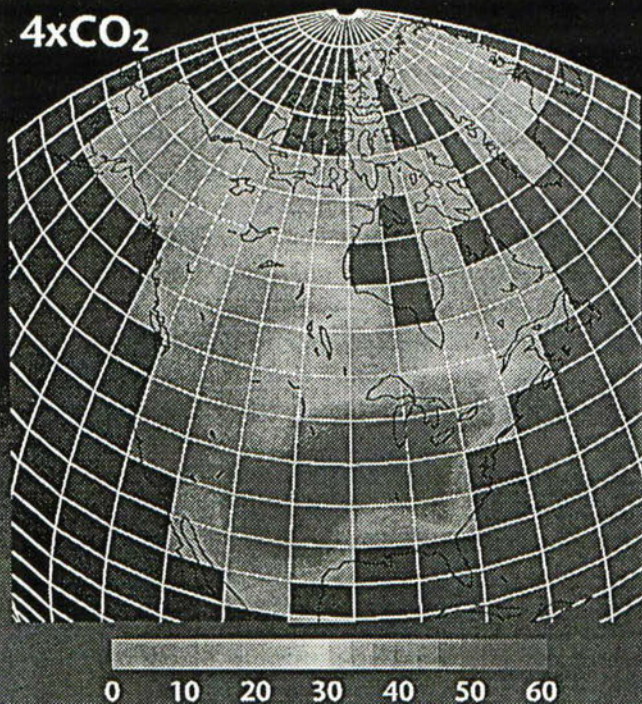


-5 0 5 10 15 20 25

Source: GFDL R15 Climate Model; CO₂ transient experiments, years 401-500.

Percent Reduction in June-August Soil Moisture

4xCO₂



States during the summer growing season (Figure 12).

^{the} If CO₂ concentration continues to rise to four times the preindustrial level, or more than 1100 ppm, the estimated temperature increase for the United States would be 15 °F to 20 °F, and soil drying could approach 30 percent to 50 percent during the growing season (Figures 13 and 14).

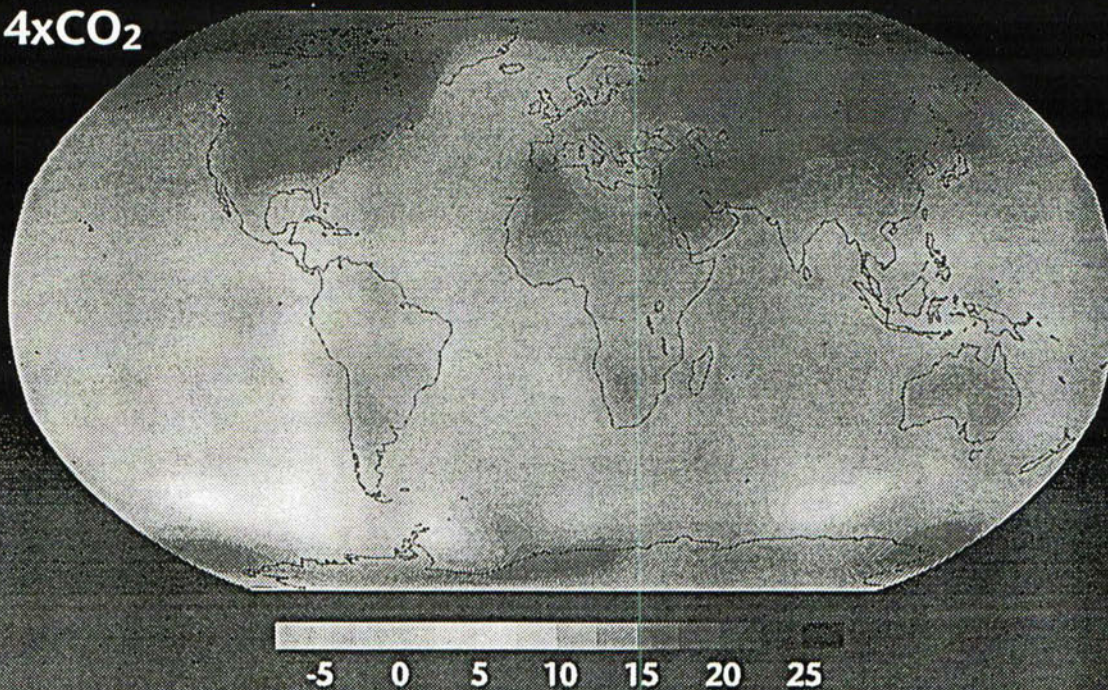
Figure 13 The extent of warming indicated in Figure 14 would lead to severe soil drying in the U.S., with deficits reaching 30 percent to 50 percent during the growing season.

Figure 14. If the CO₂ levels reach 1100 ppm, ~~our climate will stabilize at temperatures exceeding 15 °F to 20 °F higher~~ than current levels.

US temperature could be

Surface Air Warming (°F)

4xCO₂



Source: GFDL R15 Climate Model; CO₂ transient experiments, years 401-500.

Vulnerabilities and Potential Consequences

Climate changes from rapidly rising concentrations of CO₂ and other greenhouse gases could have widespread effects, many of them negative, on ecological systems, human health, and socioeconomic sectors. At the higher concentrations, uncertainty about what will happen increases. The outcome could be less dramatic than expected, but it could just as well be much more severe. The faster the rate of change in climate, the less time there will be to adapt, underscoring the importance of proceeding with great caution.

Worsening Health Effects - Climate change will impact human health in a variety of ways. Warmer temperatures will increase the risk of mortality from heat stress. For example, in July 1995, 465 deaths in Chicago were attributed to a heat wave with temperatures exceeding 90 °F day and night. By 2100, this type of event may become six times more frequent. Climate change also ~~can~~ exacerbate air quality problems, such as smog, and increase levels of airborne pollen and spores that aggravate respira-

tory disease, asthma, and allergic disorders. Because children and the elderly are the most vulnerable populations, they are likely to suffer disproportionately to both warmer temperatures and poorer air quality.

Diseases that thrive in warmer climates, such as malaria, dengue and yellow fevers, encephalitis, and cholera, are likely to spread due to the expansion of the ranges of mosquitos and other disease-carrying organisms. The result could be, for example, 50 million to 80 million additional malaria cases per year worldwide by 2100. In general, people in developing countries are more vulnerable to climate change because of limited infrastructure and capital and greater dependence on natural resources.

Rising Sea Level - Rising sea level erodes beaches and coastal wetlands, inundates low-lying areas, and increases the vulnerability of coastal areas to flooding from storm surges and intense rainfall. By 2100, sea level is expected to rise by 6 to 37 inches. A 20-inch sea level rise

The heat index is a ^{calculation} measurement combining temperature and humidity. For Washington, DC, in July, the

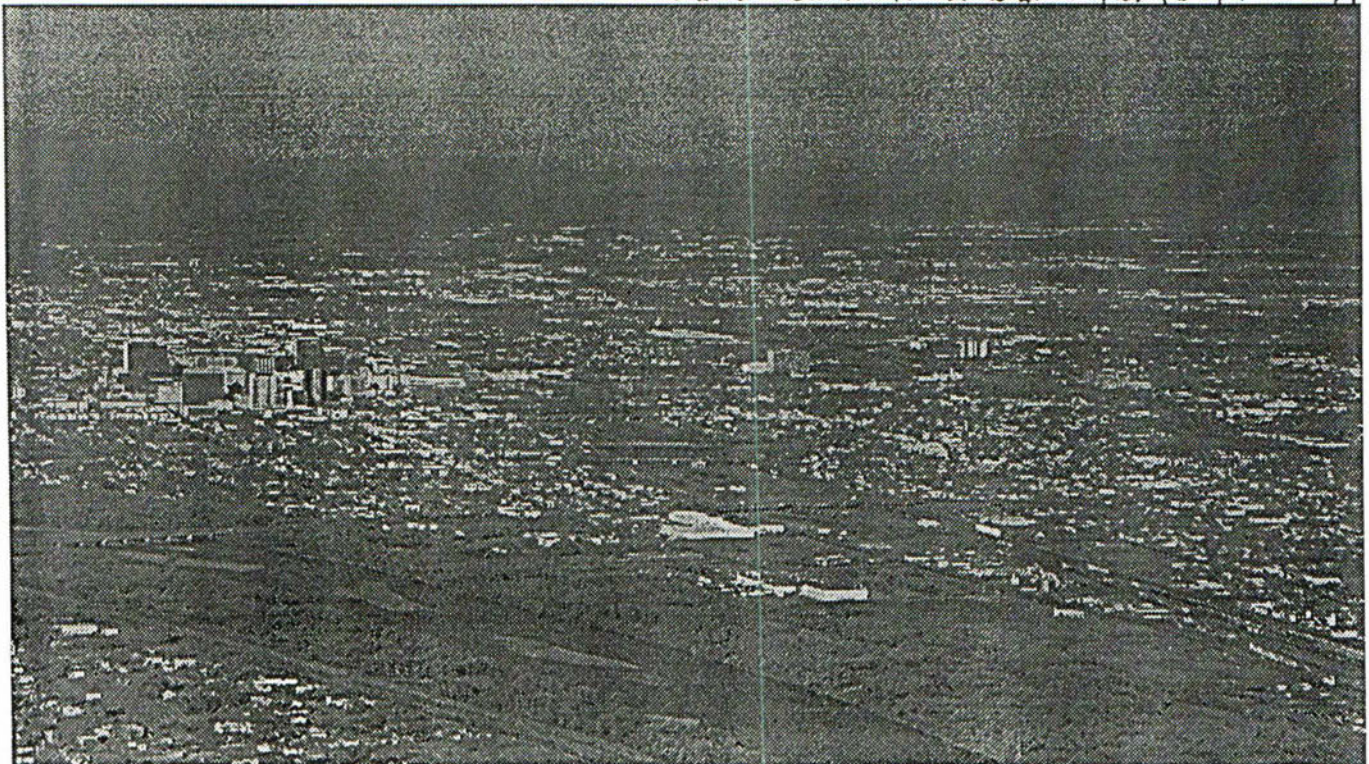


Figure 15. Higher temperatures will exacerbate urban air pollution problems such as tropospheric ozone.

with

and increased rates of transmission

2 spaces

will

heat index is now 85°.

IF CO₂ levels are double reach 550 ppm (double pre-industrial level), this will increase to 95°. IF ^{pre-ind.} CO₂ levels are quadrupled to 1100 ppm,

to 100 in 100 years

6.1-6.2 °C

associated with CO₂ levels
of 550 ppm

will result in substantial loss of coastal land in the United States, particularly along the southern Atlantic and Gulf coasts, which are currently subsiding and are particularly vulnerable. The oceans will continue to expand for several centuries after temperatures stabilize. Because of this, sea level rise may eventually exceed 80 40 inches (2 m), and could be substantially more, depending on the extent to which the Greenland and Antarctic ice sheets melt.

- A 20-inch sea level rise would double the population at risk from storm surges, from roughly 45 million at present to over 90 million worldwide. A 40-inch (1 m) rise would triple the number.

- South Florida is highly vulnerable to sea level rise of 40 inches (Fig 16). A third of the Florida Everglades has an elevation of less than 12 inches, and is vulnerable to a 1-foot sea level rise. Salt water intrusion would adversely affect delicate ecological communities and degrade the habitat for many species (Figure 16).

Disruption of the Water Cycle - Among the most fundamental effects of climate change are intensification and disruption of the water cycle.

Droughts and floods - Intensification of the water cycle will produce more severe droughts in some places and floods in others. Such events are costly. Damages from the Southern Plains drought of 1996 were estimated at \$4 billion,

South Florida Shoreline Change after a 1-Meter Rise in Sea Level

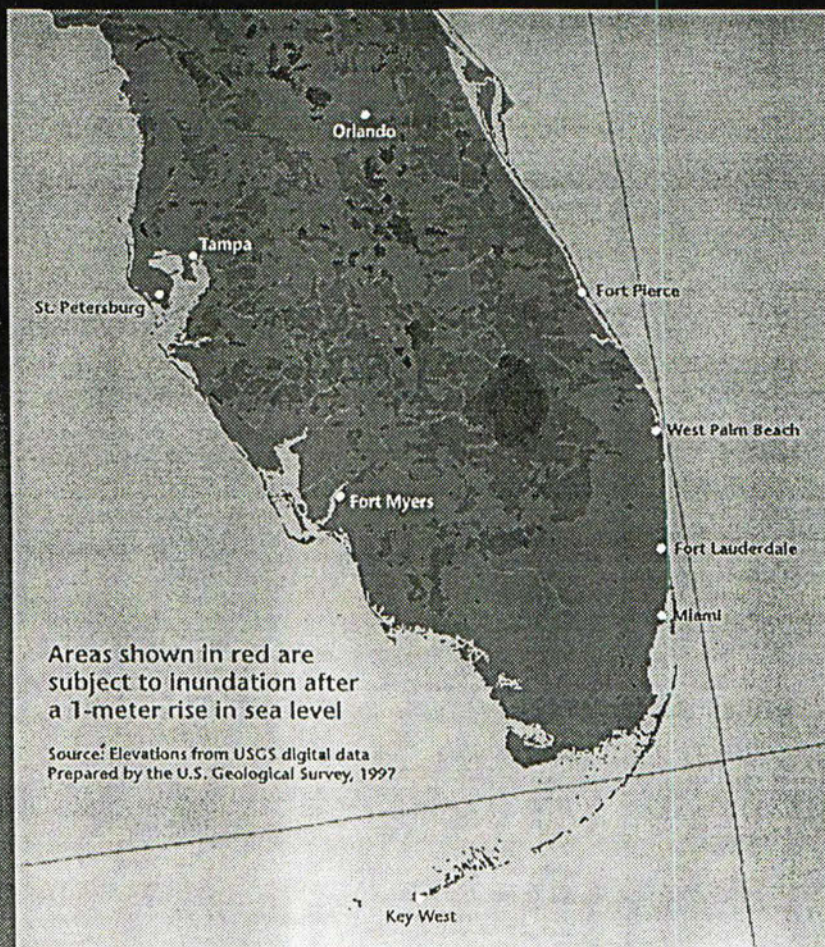


Figure 16. Sea level rise could inundate many low-lying coastal areas in Florida, and will increase the vulnerability of all such areas to storm surges.

The 1993 Pacific Northwest floods in the winter of 1993-1994 at about \$3 billion, the 1997 Ohio river flood at about \$1 billion,

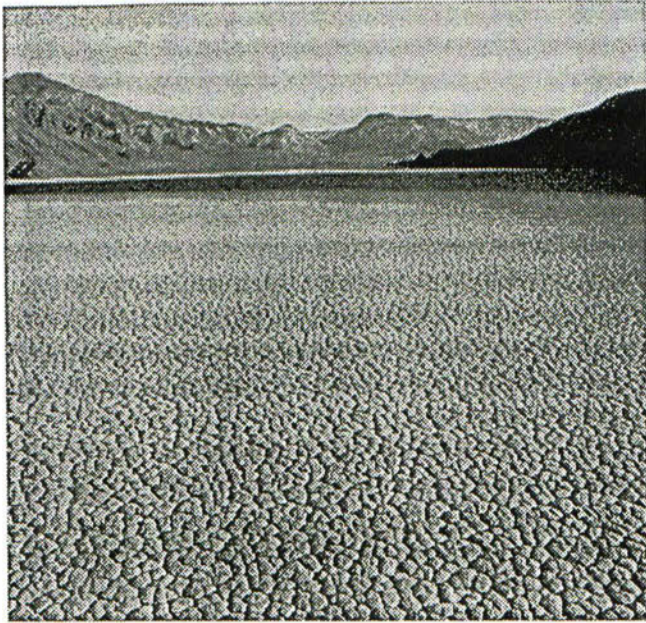


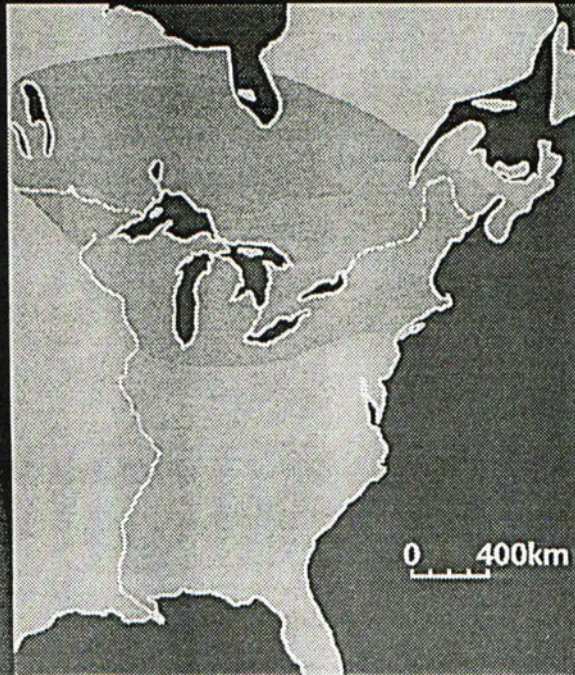
Figure 17. Severe drought will become more frequent in some regions as the precipitation patterns shift.

the 1993 Mississippi River flood damages at ~~ranged from~~ \$10 billion to \$20 billion, and the 1997 Red River flood in the Northern Plains ~~cost an estimated~~ \$2 billion. ~~at about~~

Water quality and quantity - Areas of greatest vulnerability are those where quality and quantity of water are already problems, such as the arid and semi-arid regions of the United States and the world (Figure 17).

- Climate change would likely increase water supply problems in several U.S. river basins, such as the Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado.
- Water scarcity in the Middle East and Africa is likely to be aggravated by climate change, increasing the risk of international tension among countries ~~such as Syria, Sudan, Egypt,~~ and Iraq, which depend on water supplies originating outside their borders.

Current and Projected Ranges of Sugar Maple



Prediction based on increased temperature

present range

overlap

Prediction based on increased temperature and moisture reduction

predicted range

Figure 18. Climatic shifts will force some species to migrate northwards or to higher elevations in order to stay in the appropriate climatic zone. The climatic zone for sugar maple, for example, could shift northwards into Canada. This would compromise the maple syrup industry and the fall foliage colors, both of which make New England famous.

and Changing Natural Areas.

Shifting Forests - Climate change can dramatically alter the geographic distributions of vegetation types. The composition of one-third of the Earth's forests would undergo major changes as a result of climate changes associated with a CO₂ level of 700 ppm. Over the next 100 years, the ideal range for some North American forest species could shift by as much as 300 miles to the north, far faster than the forests can migrate naturally. Economically important species, such as sugar maple, could be lost from New England by the end of the next century (Figure 18).

Such changes could have profound effects on

Changing Natural Areas - Natural ecosystems, including those that make up the U.S. system of national parks and refuges, are highly vulnerable to degradation from climate change. The composition, geographic distribution, and productivity of many ecosystems will shift, leading to reductions in biological diversity and in the

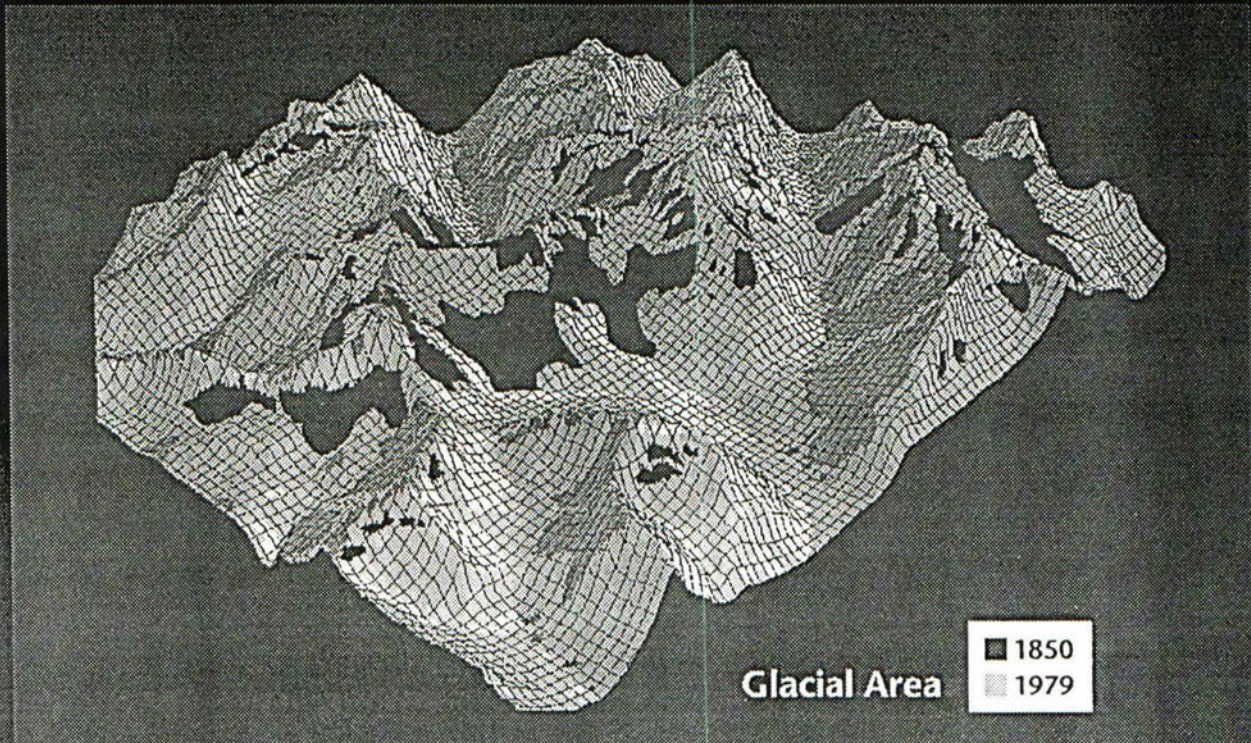
benefits they provide, such as clean water and recreation. Wetlands are particularly at risk. The wetlands of the prairie pothole region, which support half the waterfowl population of North America, could diminish in area and change dramatically in character in response to climate change. Mountain glaciers, which fluctuate rapidly in response to climate change, will shrink. The glaciers of Glacier National Park have receded steadily for decades. By 1993, there had been a 73 percent reduction in the area of eight prominent glaciers in the Park (Figure 19).

Model projections indicate that all the park's glaciers will disappear by 2030.

Challenges to Agriculture and the Food Supply - Climate strongly affects crop yields. A CO₂ concentration of 700 ppm is likely to increase crop yields in some areas by as much as 30 percent to 40 percent, but it will decrease yields in other places by similar amounts, even for the same crop. A warmer climate would

Glacial Recession in a Glacier Complex

Red Eagle, Logan, Pompelly, Blackfoot, Jackson, Harrison and Sperry Glaciers, Glacier National Park, MT



Source: USGS Biological Resources Division, Glacier Field Station, Provisional Data, 1996

Figure 19. Warmer temperatures have already led to substantial glacier melting and shrinkage in Glacier National Park, Montana. Data indicate that more than 70 percent of some of the glaciers in the National Park have already melted.

reduce flexibility in crop distribution and increase irrigation demands. Expansions of the ranges of pests could also increase vulnerability and result in greater use of pesticides. Despite potentially large changes in yields, food production is not expected to be altered substantially by global climate change, ^{overall} but there are likely to be winners and losers. Agricultural systems

in the developed countries are highly adaptable and can probably cope with the expected range of climate changes without dramatic reductions in yields. It is the poorest countries, already subject to hunger, that are the most likely to suffer significant decreases in agricultural productivity (Figure 20).

Agricultural Resources: Potential Change in Grain Yield due to Doubled CO₂



-30% -10% 10% 30%

Percent of Change in Yield

Based on GISS model;
physiological CO₂ effects included

Source: Rosenzweig and Hillel (1993)

Figure 20. Agricultural production would increase in some areas, and decline in others as the climate warms and the CO₂ levels in the atmosphere increase. Although many scientists believe that global risk from hunger will not increase with climate change, there will be local winners and losers. Farmers may need to shift crops, or re-locate agricultural lands. The need for irrigation may also increase.

Conclusion

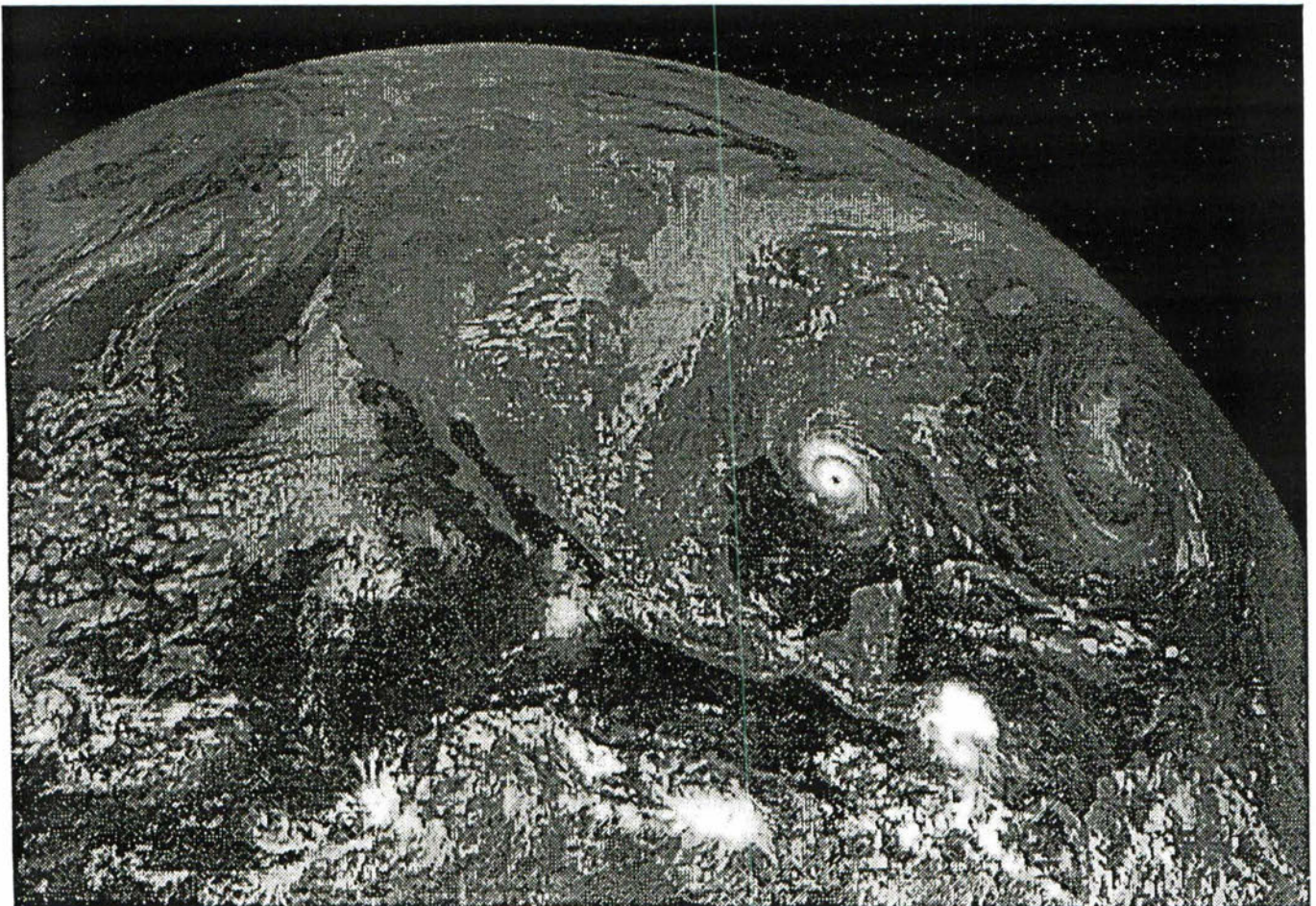
Earth's atmosphere is rapidly changing. As the world's expanding population burns large quantities of fossil fuels and simultaneously cuts down large expanses of forests worldwide, the concentrations of CO₂ and other greenhouse gases are building up in the atmosphere. There is mounting evidence that this shift in Earth's atmosphere will lead to global warming and potentially major climatic disruptions.

Many aspects of our lives are already vulnerable to climate extremes and variability. Global warming and other climatic disruptions will, in turn,

amplify the effects of other stresses and affect our lives in many ways. Our health may be compromised, our food supply threatened, our natural areas severely disturbed, and our supply of freshwater in some areas limited as Earth's climate changes.

The more knowledgeable we ^{have} are about our vulnerabilities to climate change, the better prepared we will be to make wise decisions about our future course. Investing now to protect Earth's climate will enable our children to live in a world that is not dramatically altered by an enhanced greenhouse effect.

and grandchildren



Credits

Figure 1: Greenhouse effect

Source: ©Melody Warford, 1995

Figure 2: Smokestacks photograph

Source: ©P. Grabhorn, 1994

Figure 3: Deforestation photograph

Source: ©P. Grabhorn, 1996

Figure 4: CO₂ record, 1860 to present

Source: Data from Neftel et al & Keeling

Figure 5: CO₂ and temperature record over last 160,000 years through present only

Source: Data from Barnola et al, Vostok Ice Core; data available from the Carbon Dioxide Information Analysis Center, Oak Ridge, TN

Figure 6: Developed vs developing country CO₂ emissions, 1990 vs 2035 pie charts

Source: IPCC, IS92A Emission Scenario

Figure 7: Global average temperature

Source: Data from J. Hansen et al, GISS

Figure 8: Mississippi Flood photograph

Source: ©P. Grabhorn, 1993

Figure 9: Mississippi Flood Landsat 5 Thematic Mapper Images

©EOSAT Corporation, Lanham, MD

Figure 10: CO₂ and temperature record over last 160,000 years, continues into future

Source: Data from Barnola et al, and IPCC IS92A Emission Scenario

Figure 11: 2xCO₂ surface air warming

Source: Manabe & Stouffer, 1994, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ

Figure 12: 2xCO₂ reduction in soil moisture

Source: Manabe & Stouffer, 1994, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ

Figure 13: 4xCO₂ surface air warming

Source: Manabe & Stouffer, 1994, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ

Figure 14: 4xCO₂ soil moisture reduction

Source: Manabe & Stouffer, 1994, NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ

Figure 15: Urban smog photograph

Source: ©P. Grabhorn, 1993

Figure 16: South Florida shoreline under sea level rise

Source: Red Data - USGS, Map Visualization - ©C. Grabhorn, 1995

Figure 17: Dry river bed photograph

Source: ©P. Grabhorn, 1994

Figure 18: Sugar maple

Source: Margaret Davis, Univ. Minnesota

Figure 19: Glacier retreat in Glacier Natl Park

Source:

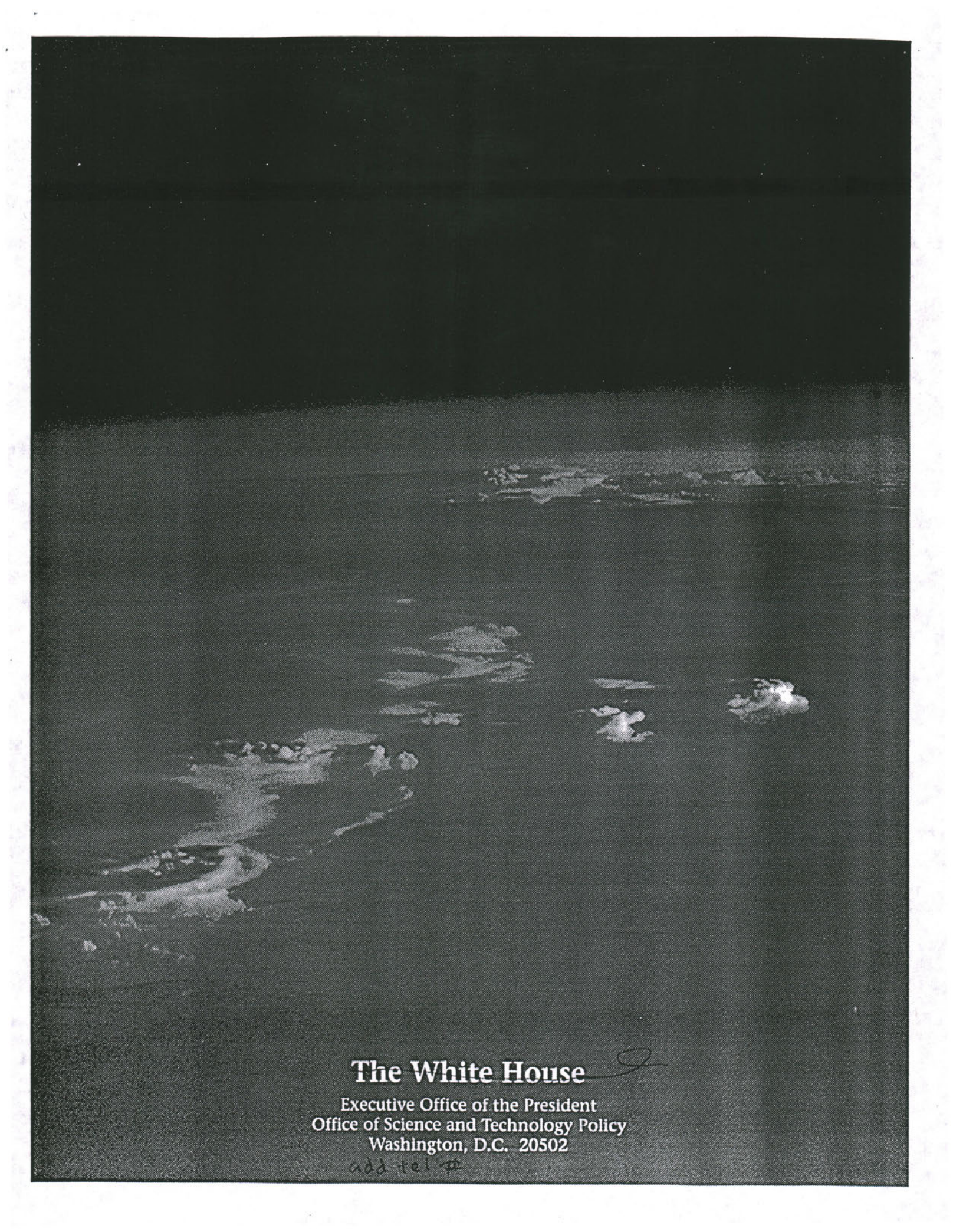
Figure 20: Agricultural resources under 2xCO

Source: Rosenzweig & Hillel, 1993, Goddard Institute for Space Studies

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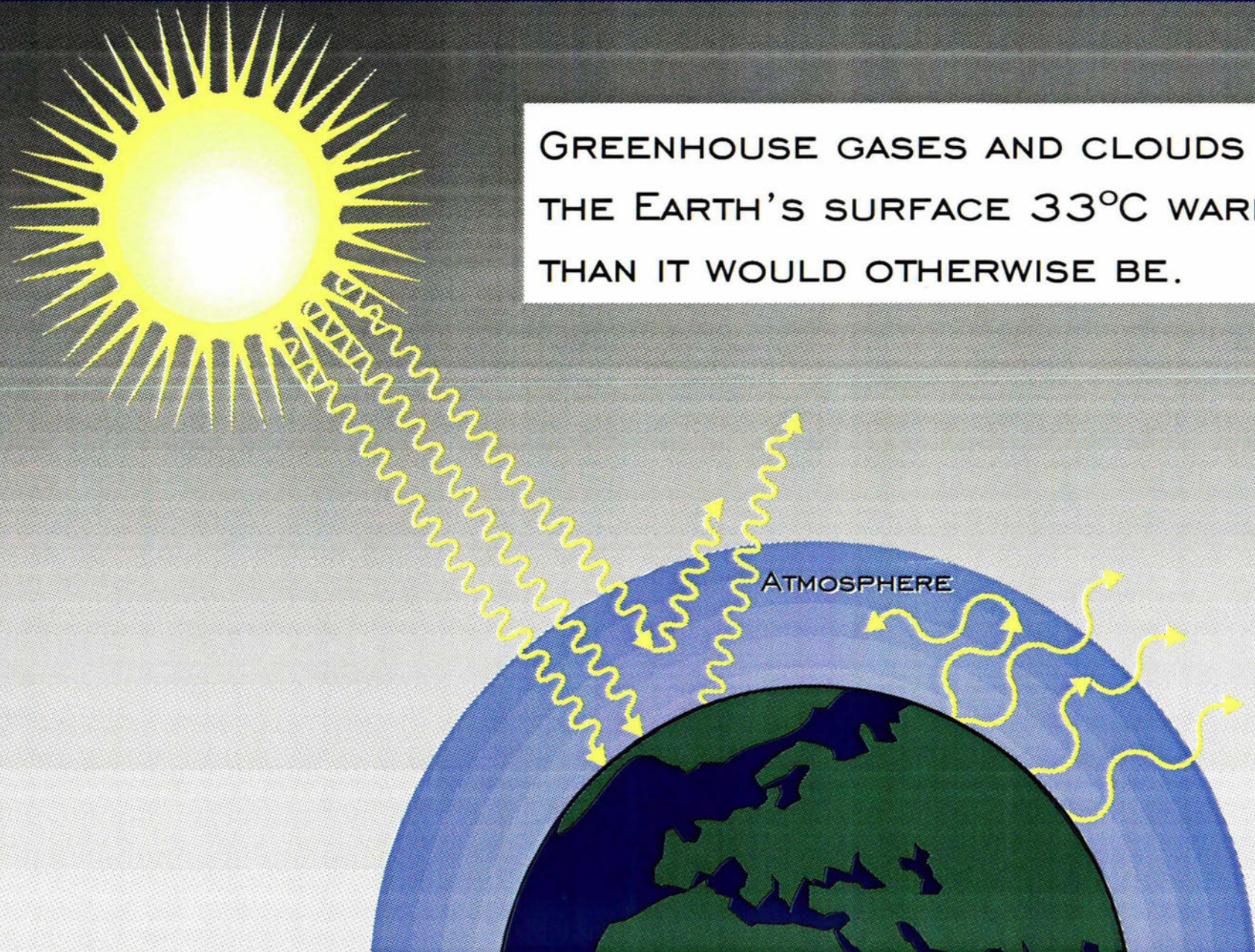
GLOBAL CLIMATE CHANGE INFORMATION PACKET

PREPARED FOR THE CABINET 7/23/97

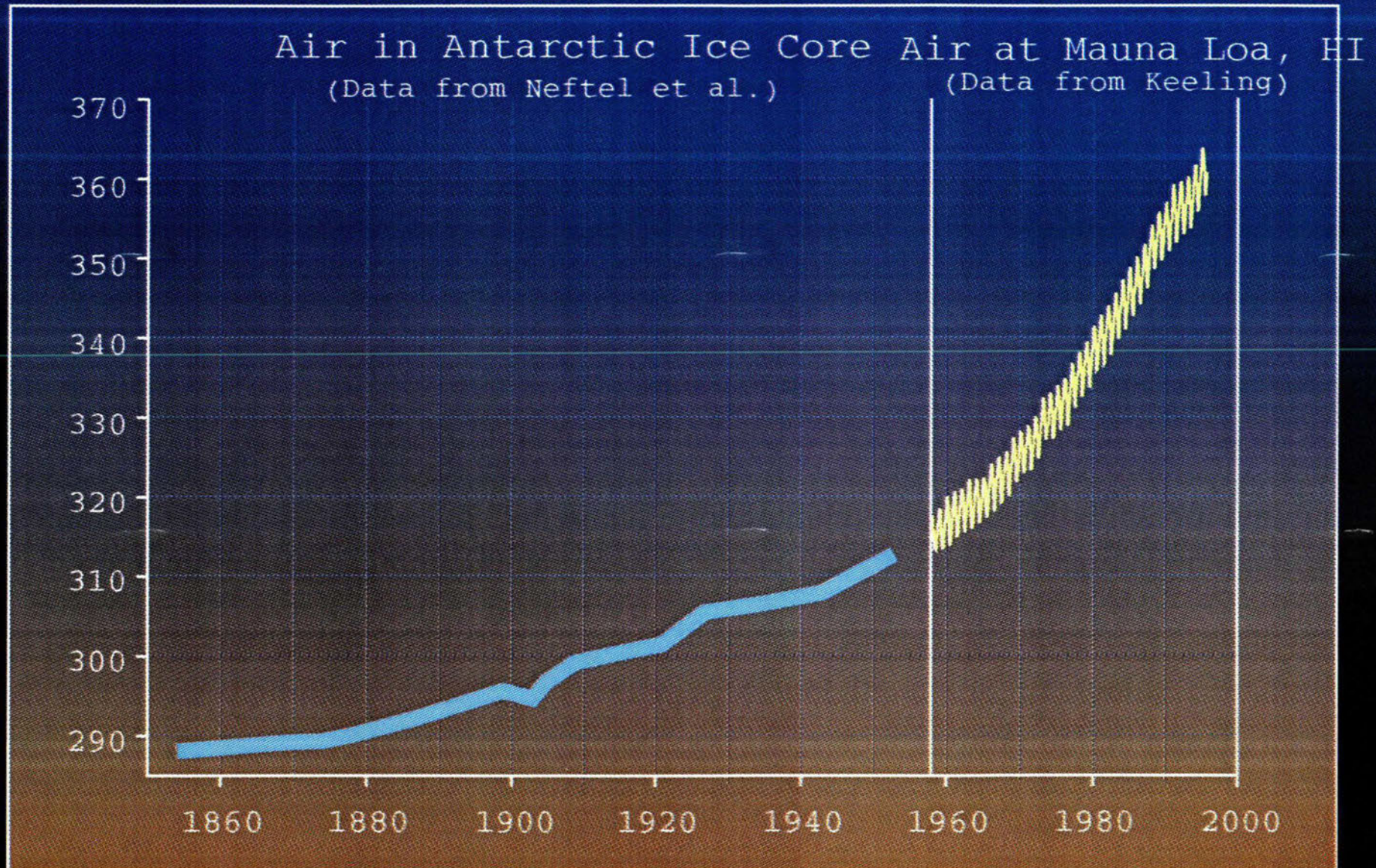


THE GREENHOUSE EFFECT

GREENHOUSE GASES AND CLOUDS KEEP THE EARTH'S SURFACE 33°C WARMER THAN IT WOULD OTHERWISE BE.

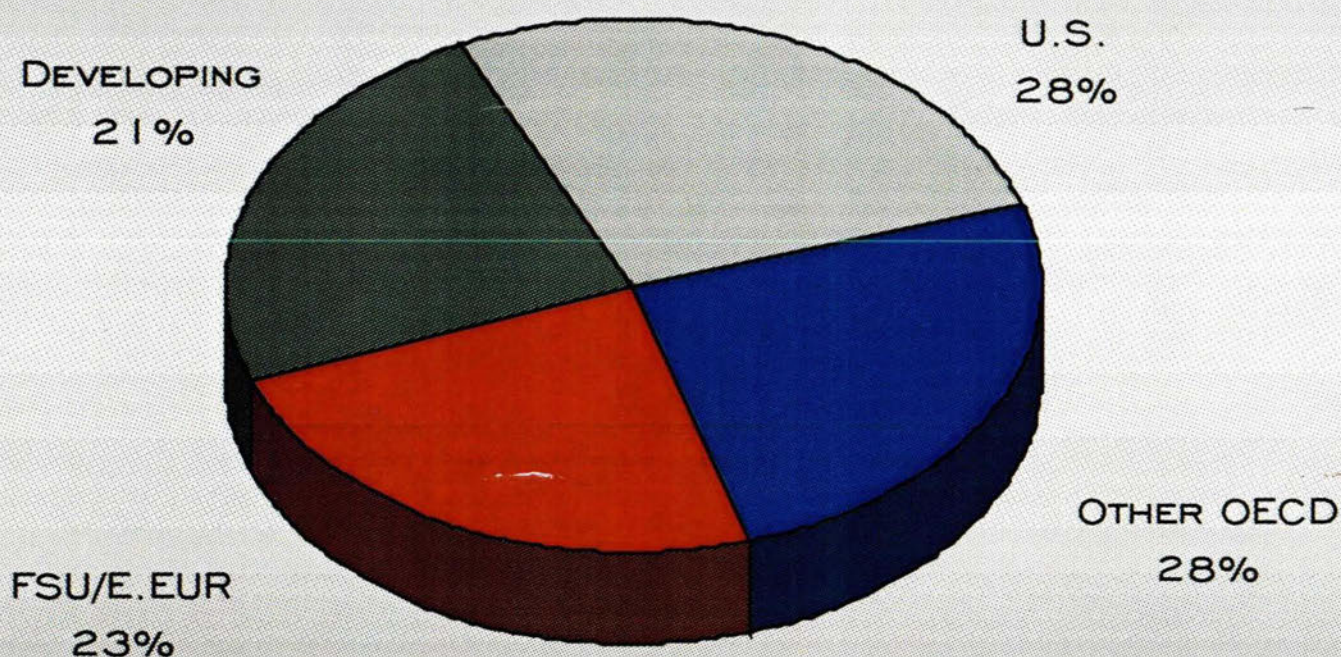


Carbon Dioxide Concentrations



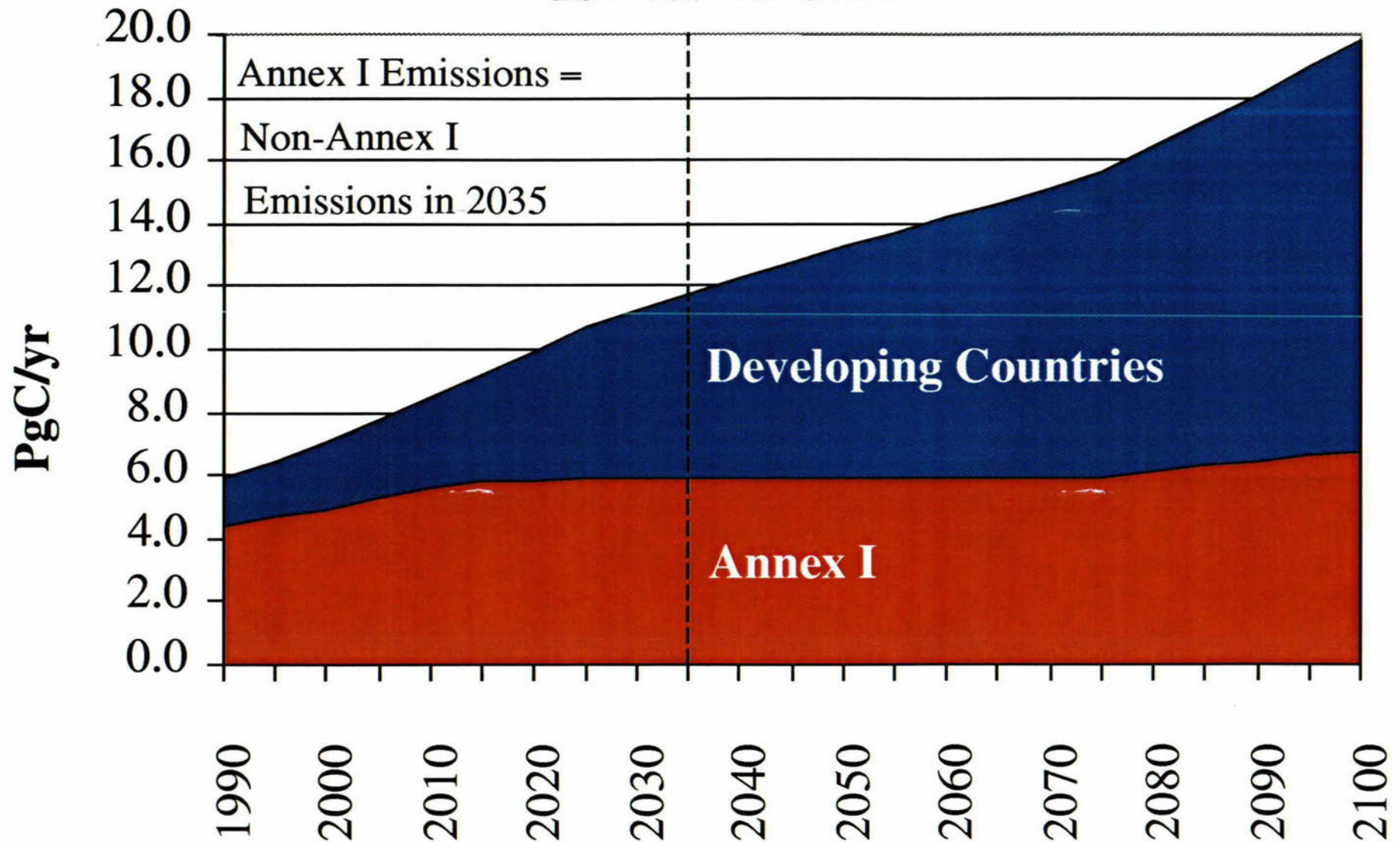
195 - 199 : CUMULATIVE CO₂ EMISSIONS FROM FOSSIL ENERGY AND CEMENT PRODUCTION

GLOBAL TOTAL: 583 BILLION TONNES CO₂

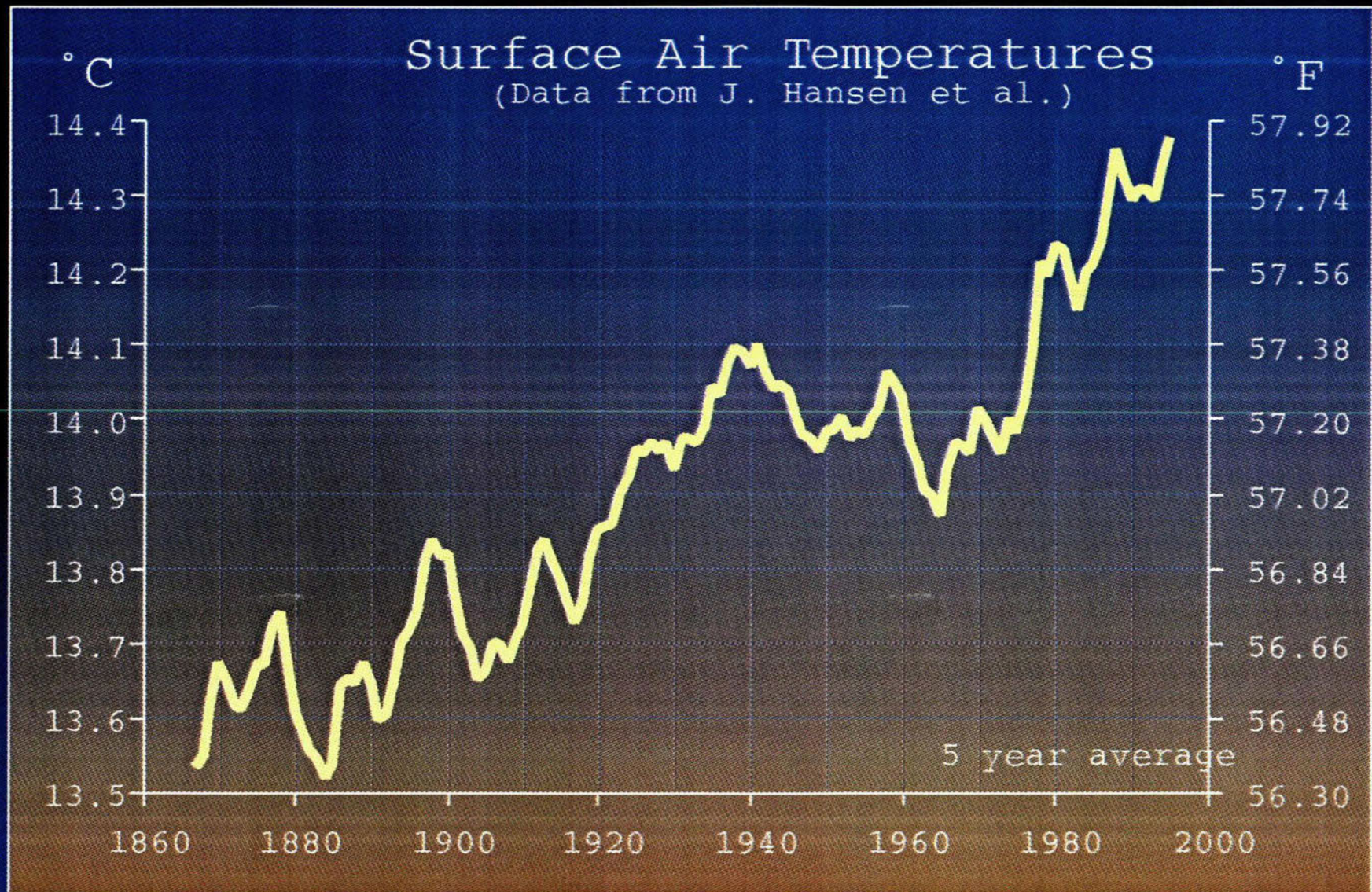


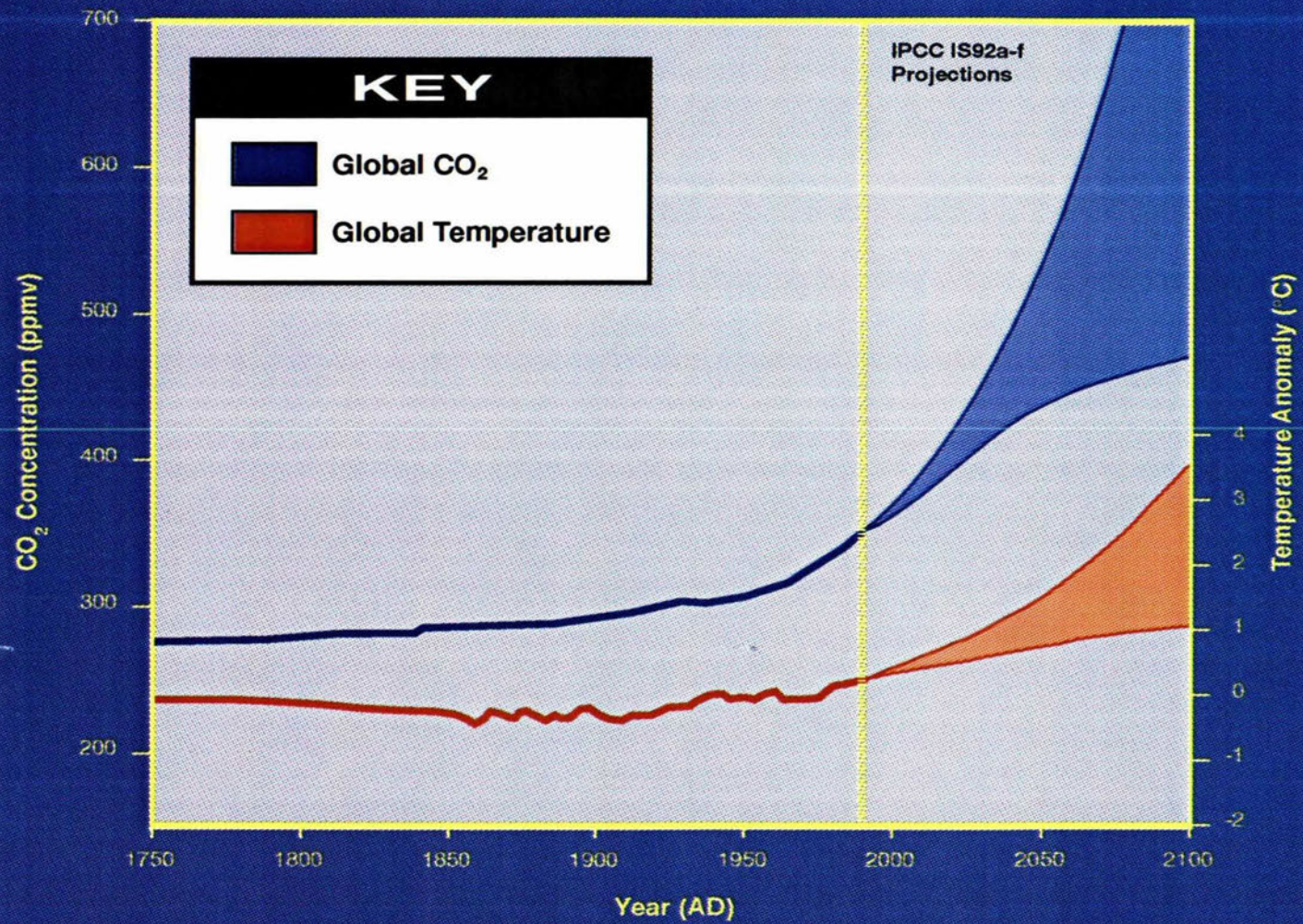
SOURCE: MARLAND ET AL. (1995)

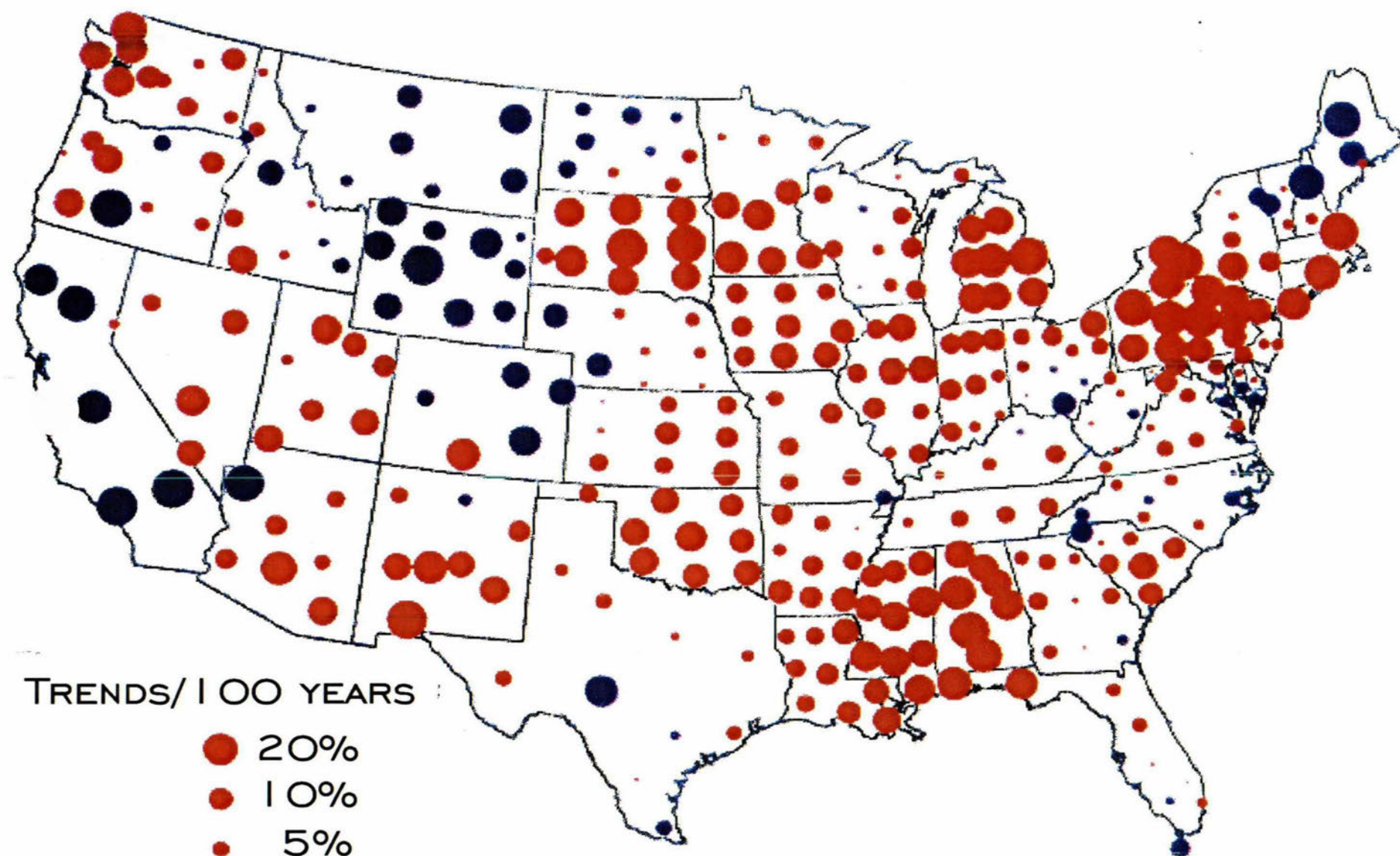
Annex I and Non-Annex I Fossil Fuel Carbon Emissions: Business As Usual



Global Average Temperature

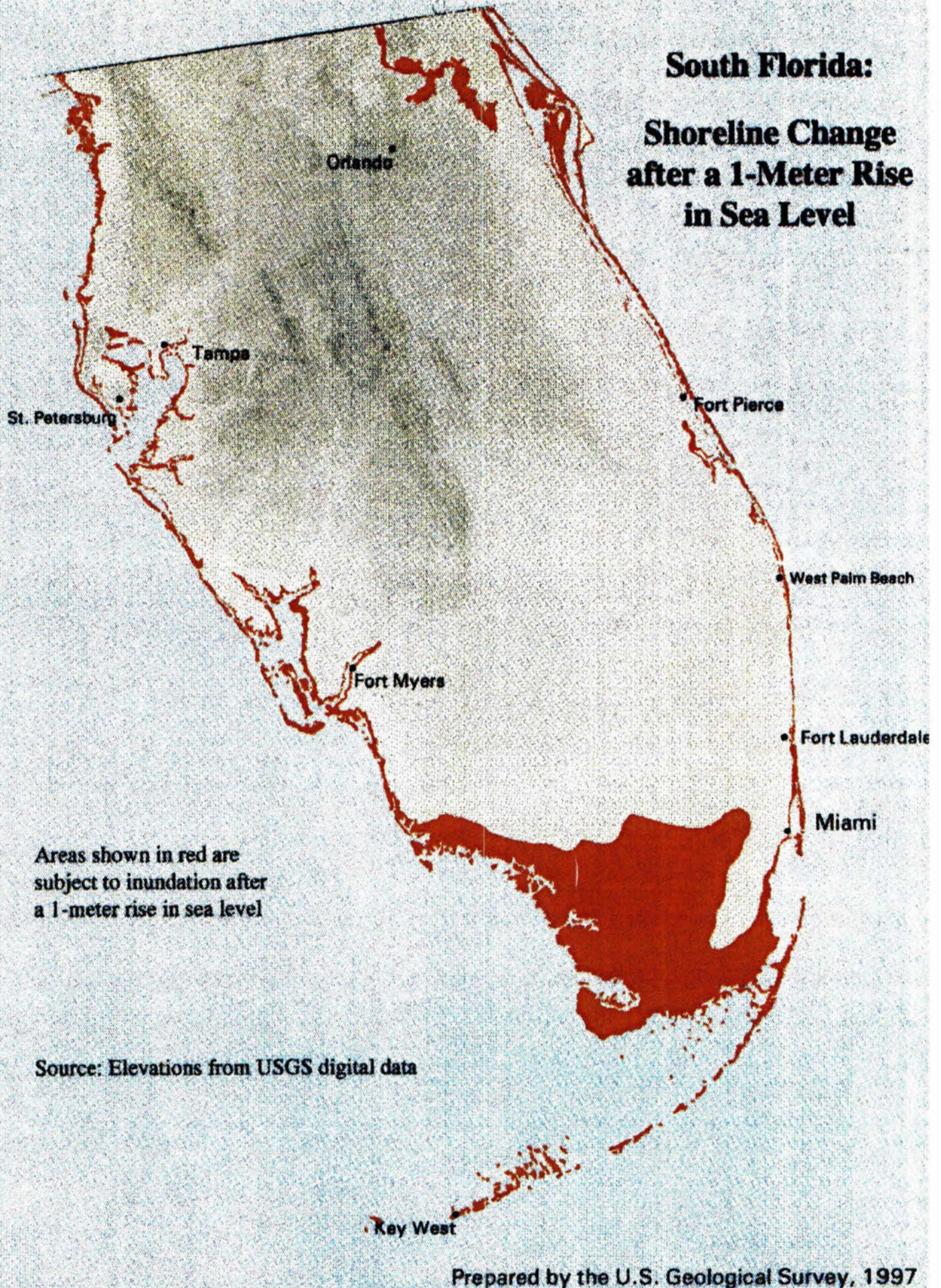




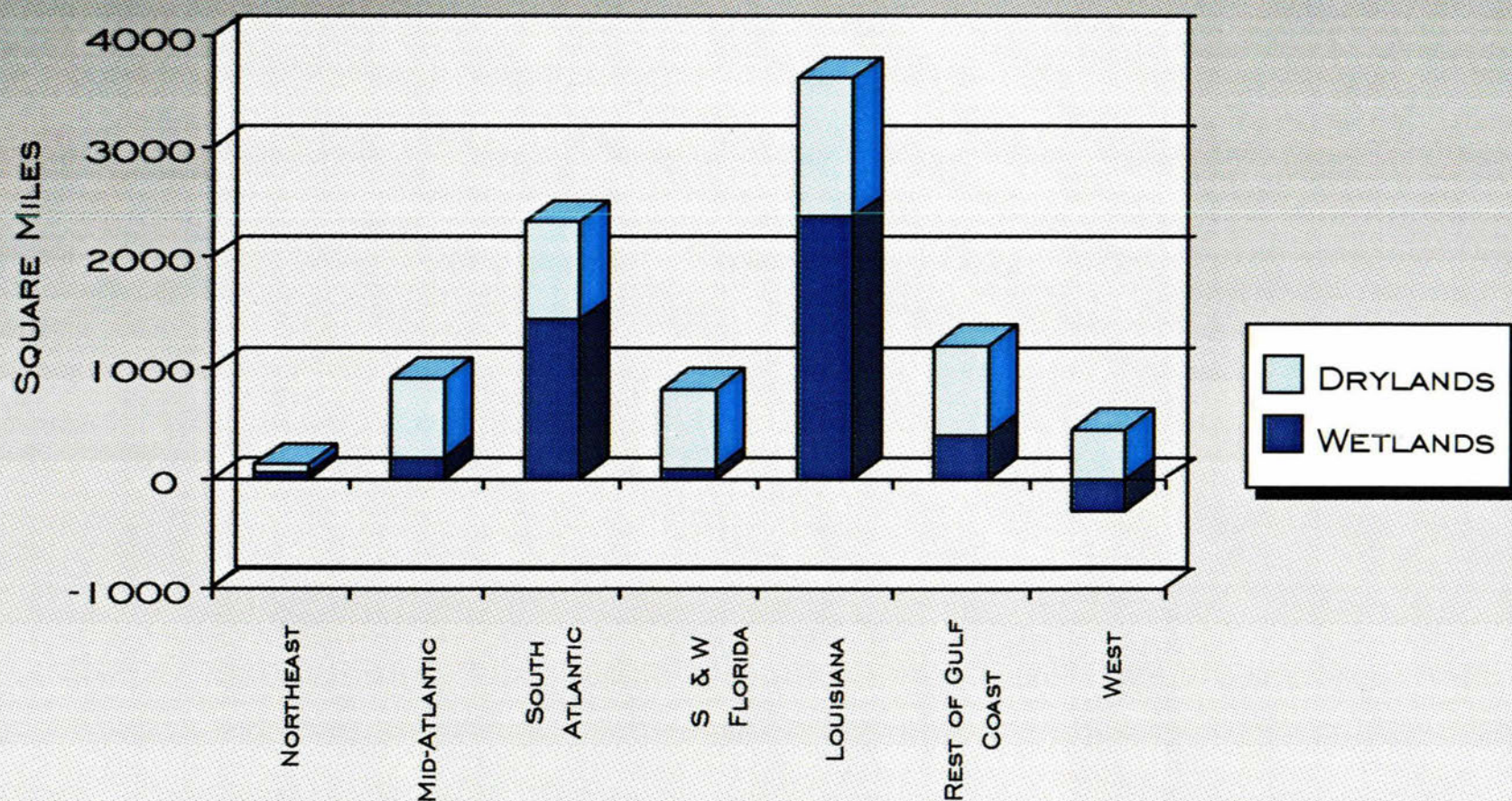


Precipitation trends (1990-present, in percent of normal annual precipitation) within state climatic divisions. The diameter of the circle centered within each climatic division reflects the magnitude of the trend. Larger circles have the greater trends. Red reflects increasing precipitation and blue decreasing.

**South Florida:
Shoreline Change
after a 1-Meter Rise
in Sea Level**

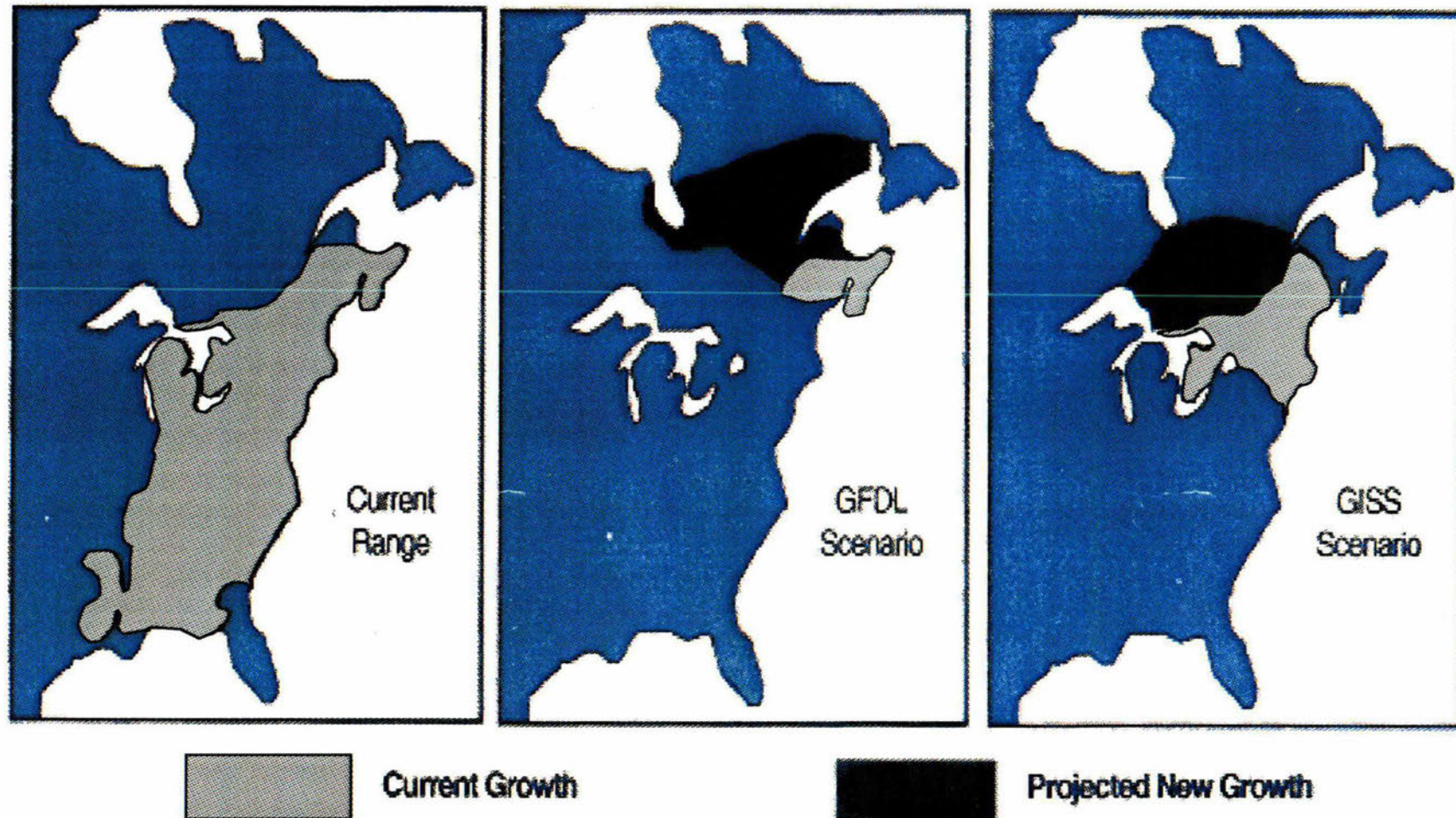


U.S. COASTAL LANDS AT RISK FROM A 20-INCH SEA LEVEL RISE IN 2100

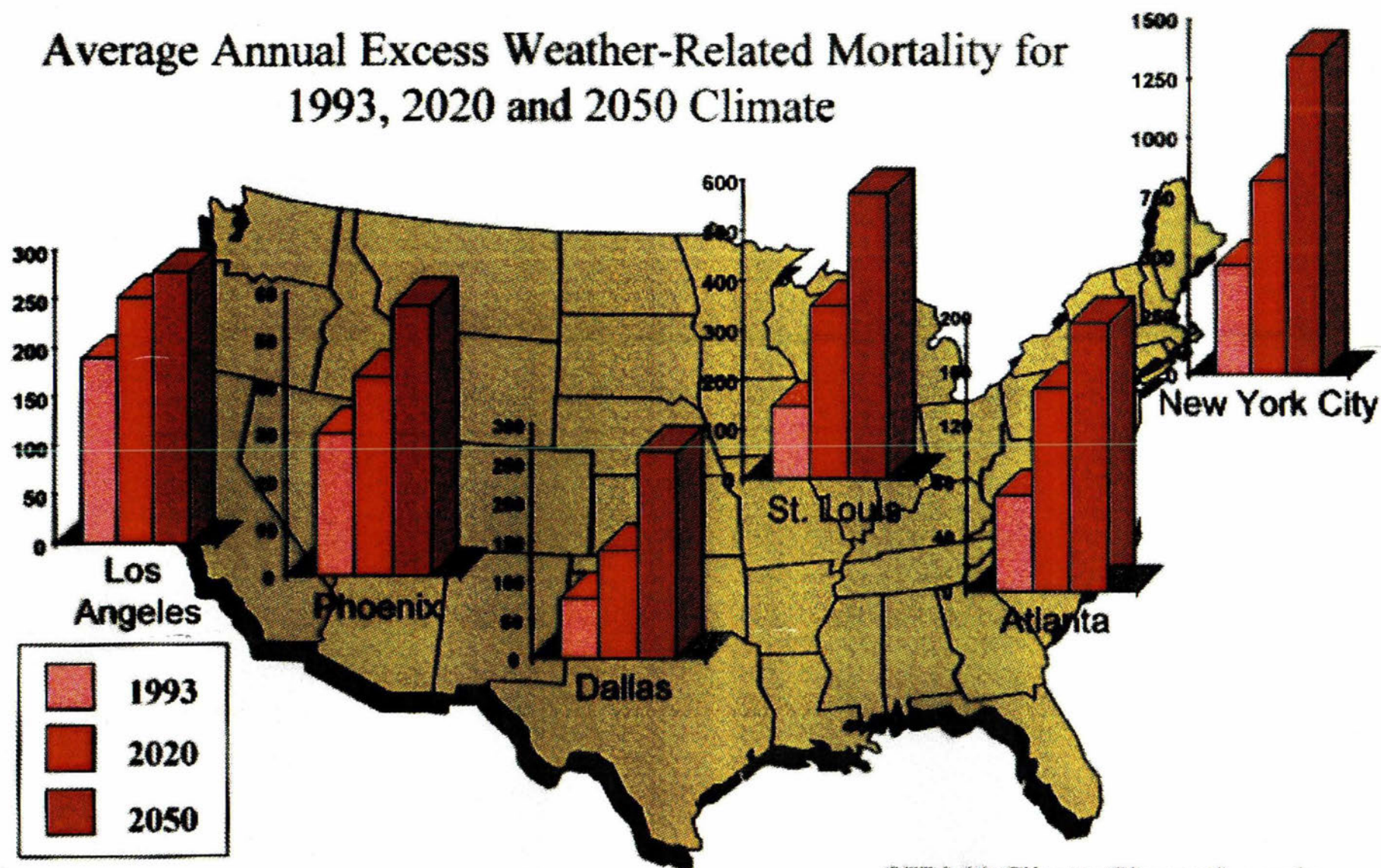


SOURCE: U.S. EPA (1989).

CURRENT AND PROJECTED RANGES OF BEECH TREES IN THE U.S. UNDER TWO MODEL SCENARIOS



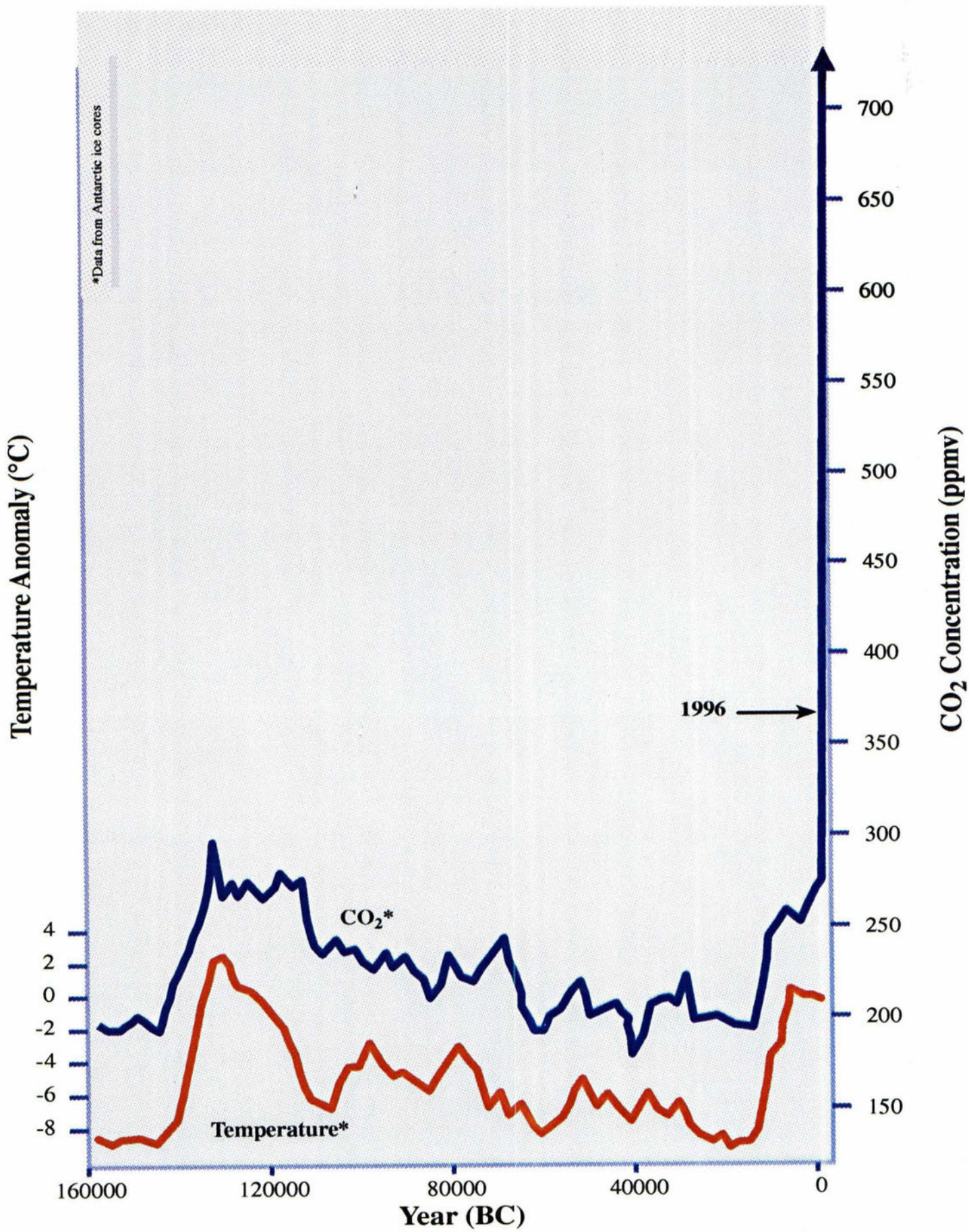
Average Annual Excess Weather-Related Mortality for 1993, 2020 and 2050 Climate



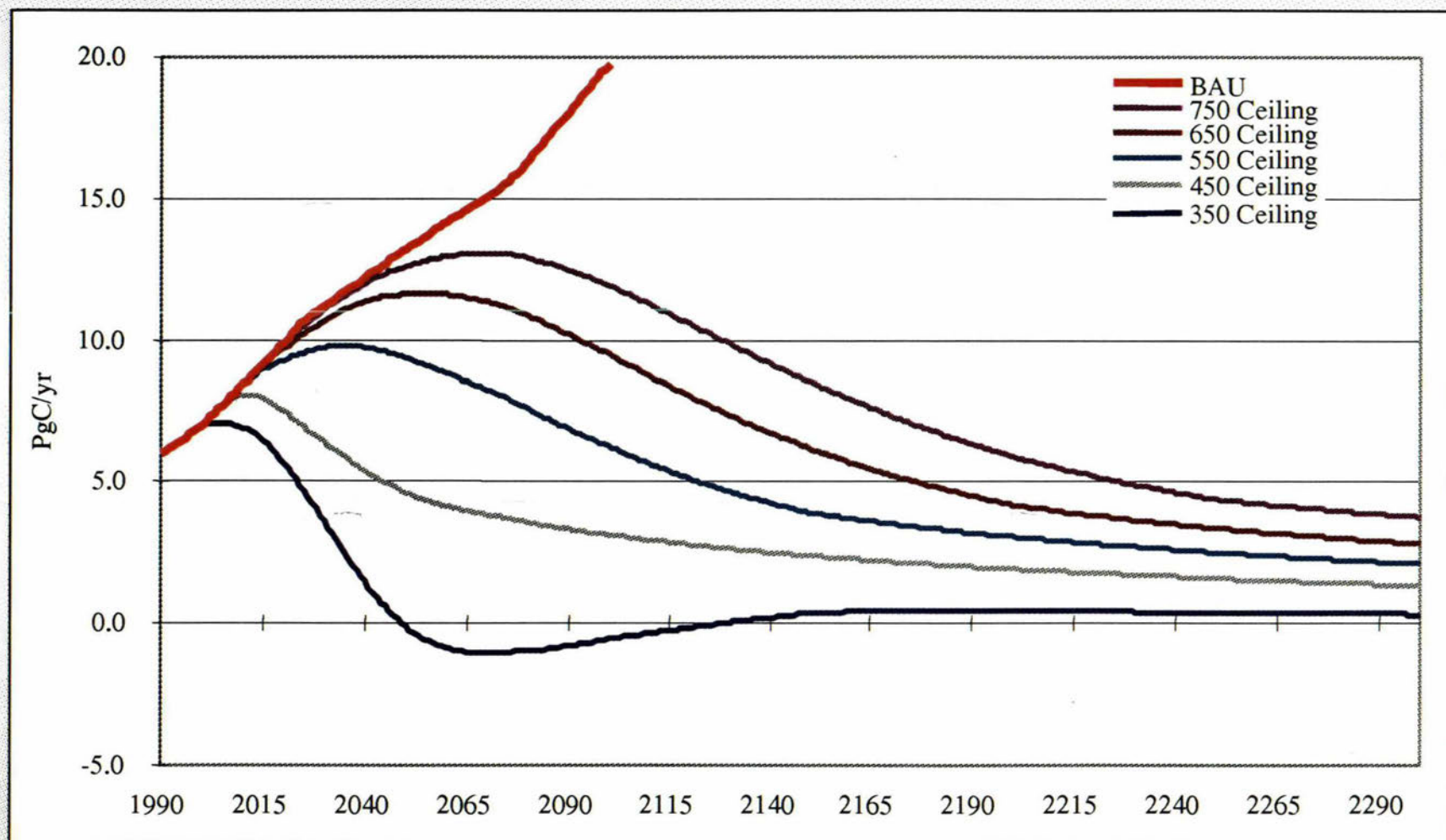
Sources: Kalkstein and Green (1997); Chestnut et al.(1995)

GFDL89 Climate Change Scenario

Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate

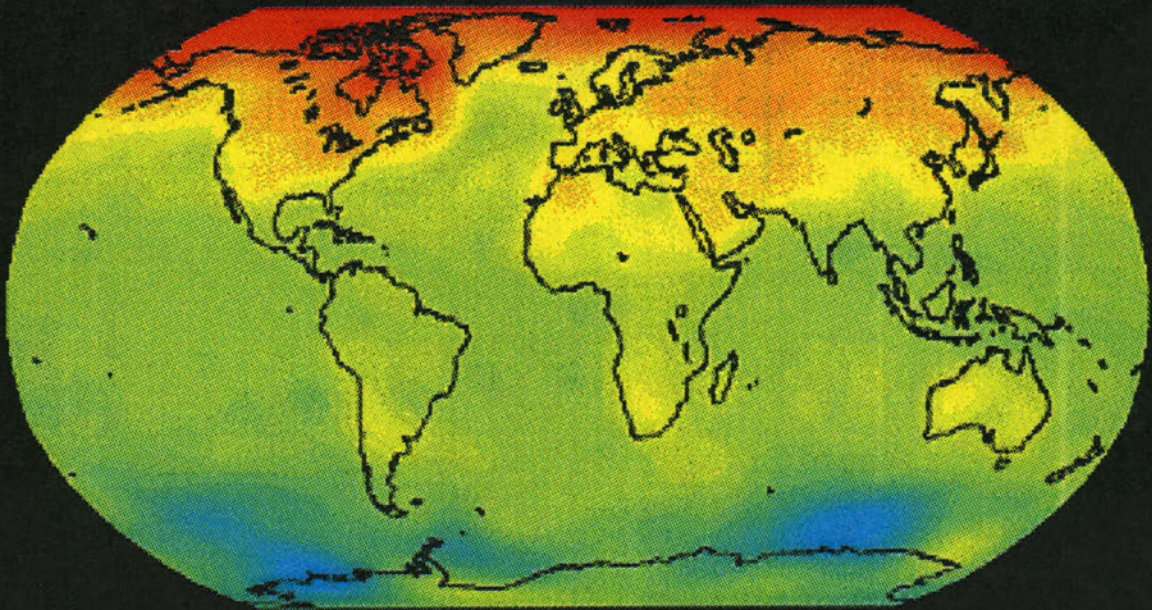


ATMOSPHERIC STABILIZATION EMISSIONS PATHS

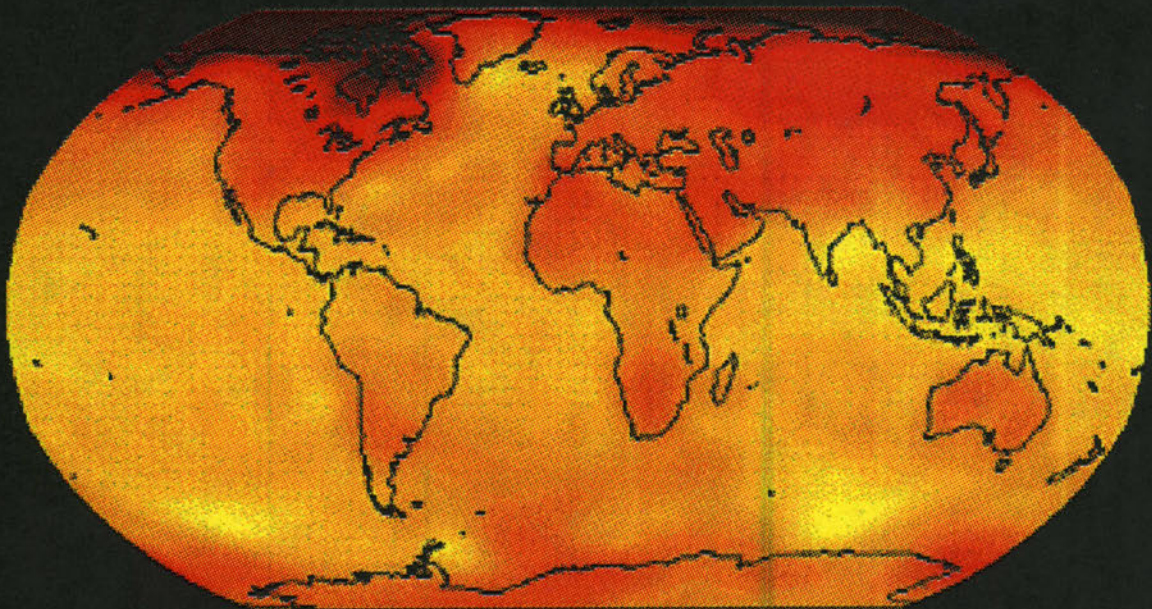


SURFACE AIR WARMING (°F)

2xCO₂



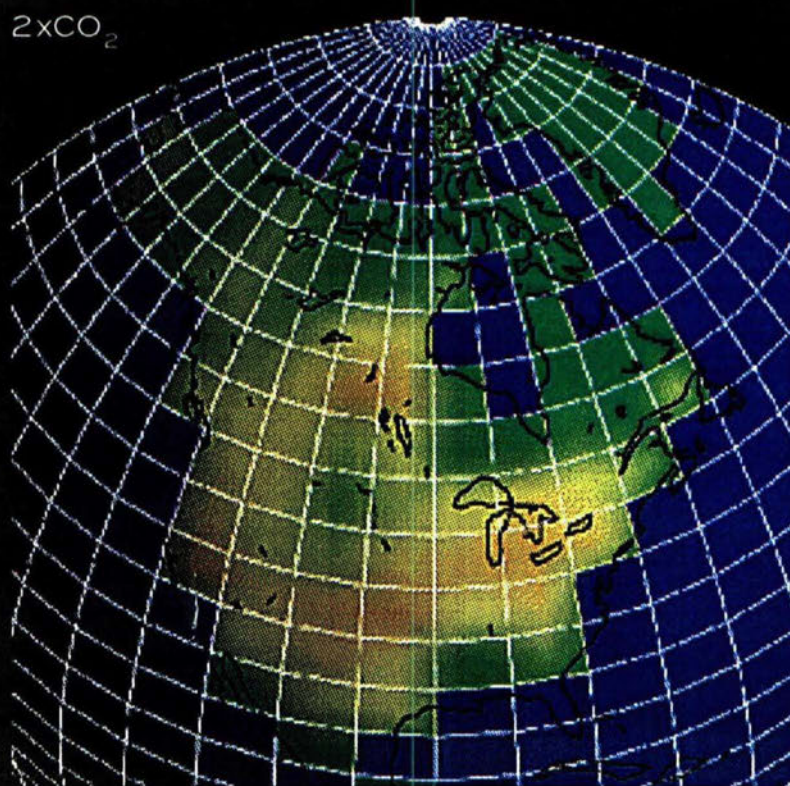
4xCO₂



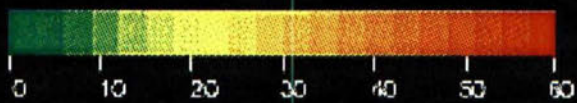
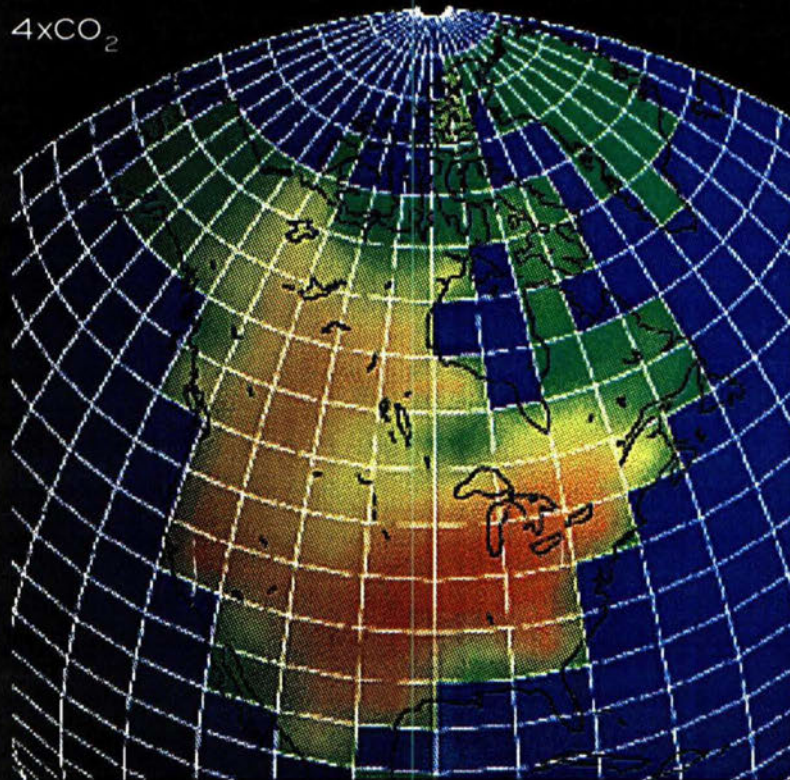
SOURCE: GFDL R15 CLIMATE MODEL; CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

2xCO₂



4xCO₂



OSTP Annotation for Graphics Package (7/23/97)

There is a strong scientific consensus that human activities are affecting the global climate as stated by the Intergovernmental Panel on Climate Change (IPCC). This represents more than 2000 scientists from more than 50 countries.

Figure 1: Greenhouse Effect

There is a natural greenhouse effect that keeps the Earth 33 degrees C, or 60 degrees F, warmer than it would be. Without this effect, life would not be possible. Water vapor, CO₂, methane, nitrous oxide, and other trace gases trap heat as it is re-radiated out to space.

Figure 2: Changes in CO₂ Over Time

Since pre-industrial times, humans have added to the natural greenhouse effect by releasing additional greenhouse gases into the atmosphere. Burning of fossil fuels for energy is the primary source of emissions (about 6 billion metric tons of carbon per year); changing land-use patterns through agriculture and deforestation also contribute another 1-2 billion metric tons per year. Since the Industrial Revolution, atmospheric concentrations of carbon dioxide -- the most important greenhouse gas -- have increased about 30%, from 280 to 360 parts per million by volume (ppm). Other greenhouse gases have also increased.

Figure 3: Cumulative CO₂ Emissions, 1950-1990

Whose emissions are in the atmosphere? Today, developed countries account for most of the concentrations in the atmosphere (for example, the U.S., which has 4% of the world's population, accounts for more than 25% of the greenhouse gases emitted into the atmosphere over the past 40 years.)

Note that developing countries, with 80% of the current world population, accounted for only 21% of the past four decade's emissions. Of course that will change: 90% of the world's population growth over the next few decades will take place in developing countries. Per capita energy use -- which averages about 1/10 to 1/20th of ours -- will increase. (For example, there is only 1 car per 2,000 people in China).

Figure 4: Projected CO₂ Emissions

Under business as usual, we expect emissions from the developing countries to rapidly increase, equaling those of Annex 1 (US, OECD, former Soviet Union, and Eastern Europe by about 2035 and continue to climb.

Figure 5: Global Temperature, 1860 to Present

What has happened to date? Over the last century, the global mean surface temperature increased by about 0.5 degrees C (almost 1.0 degree F). The surface temperature this century is as warm or warmer than any century since at least 1400 AD. The last few decades have been the warmest this century. The ten warmest years this century have all occurred since 1980, and 1995 was the warmest year on record.

Figure 6: Projections of CO₂ and Temperature to 2100 Under Business As Usual

Where are we headed? Under a range of plausible scenarios for emissions, to another 2-6 degrees F by 2100.

Figure 7: US Precipitation and Drought Trends Over The Last 100 Years

What does warming do? A warmer earth essentially speeds up the planet's hydrological cycle or water cycle. There is more evaporation meaning there is more water in the atmosphere that will come down as rain or snow. The increased evaporation will also lead to drying in some areas, so we expect both more soil drying and more precipitation.

Figure 8: Florida Sea-level Rise

Warming the ocean causes sea-level to rise -- mostly from thermal expansion of water, some from melting of sea ice and glaciers. Here is what a 1 meter rise in sea-level will do to Florida.

Figure 9: U.S. Coastal Lands at Risk From a 20" Sea-level Rise

This shows the U.S. land loss (which totals about 7000 square miles) for a 20 inch sea-level rise -- the scientists' best guess by the year 2100. The Atlantic and Gulf Coasts are particularly vulnerable.

Figure 10: Shifting Beech Tree Ranges Under 2 Model Runs

Warming the planet and altering rainfall also shift the ideal ranges for ecosystems. The left panel shows the current range of beech trees, the two right panels are for model projections of their future range. IPCC estimates that 1/3 of the Earth's forests could undergo a major change in vegetation: the Northeast United States will likely lose beech trees and sugar maples. Western conifer forests will decrease in the area. There will also be significant shifts in the ideal range for many agricultural crops (likely to cause more hunger especially in the tropics).

Figure 11: Heat-related Deaths Projected for the US

Heat-related mortality and illness will increase. (if this graph were of major cities in developing countries, all of the numbers would be in thousands.) Reduced air quality will exacerbate respiratory disease, asthma, and allergic disorders. Geographic ranges for disease will expand, leading to an increase in disease such as malaria, dengue, and yellow fever. 50 to 80 million additional cases of malaria per year are projected worldwide.

Most impacts research has only evaluated the effects of a doubled CO₂ world equilibrium. We must also begin to understand what impacts might be experienced if atmospheric concentrations more than double. Which is where we are headed.

Figure 12: CO₂ and Temperature Over the Last 170,000 Years as Measured in Ice Cores (Vice President's Favorite Chart)

Where will business as usual take atmospheric concentrations? In 100 years, through 710 ppm -- approaching 3 times pre-industrial levels -- levels not seen in the last 50 million years. This rate is a geographic blink of an eye, much faster than what natural systems have been exposed to.

Figure 13: Emissions as Usual versus Stabilization Paths

Stabilizing the atmospheric concentration of greenhouse gases is the goal of the treaty. Note that to achieve a 550 ppm concentration target -- which represents about a doubling in atmospheric CO₂ concentrations -- worldwide emissions must veer off of Business as Usual (BAU, red line) in the next 15 years and begin declining steeply during the second quarter of the century.

Figure 14: U.S. Temperatures in a 2 times and 4 times CO₂ World

This map centered over the US shows how average temperature increases for a 2 times and 4 times CO₂ world -- 5 to 10 degrees F for a doubling, but 15 to 20 degrees F for a quadrupling (warming is amplified at higher latitudes).

Figure 15: North American Soil Moisture in a 2 times and 4 times CO₂ world

In the growing season, soil moisture deficits would approach 30-50% for quadrupling, as opposed to 10 to 30% for doubling.

We clearly wish to avoid these impacts.

Todd - This is the final - we will hit
the print button ~~at~~ Thursday
PM unless you stop us! Roman



(Video
will be
done its
3rd edit
over the
weekend)

GLOBAL CLIMATE CHANGE

AN EAST ROOM ROUNDTABLE

The White House

July 24, 1997



To obtain additional information, contact:

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Proceedings

INTRODUCTION BY THE VICE PRESIDENT:

On behalf of the President and the First Lady, it is my pleasure and honor to welcome all of you to the White House.

Today we hear about the concerns of scientists. This Administration has always worked on the simple principle that science must inform policy decisions. Scientists are by nature a cautious group, but the world's scientific community is clearly telling us that they believe we are disrupting the balance of the world's climate. In the words of the 2,000 scientists who participated in the Intergovernmental Panel on Climate Change (IPCC), there is "a discernible human influence on global climate." Moreover, recently more than 2,600 scientists signed a letter about global climatic disruption that we'll be hearing more about later.

"Scientists are by nature a cautious group, but the world's scientific community is clearly telling us that they believe we are disrupting the balance of the world's climate."

— Vice President Al Gore

And now I would like to introduce the person who is leading our country, and the world, toward recognition of what must be done to deal with this issue. It is my honor, ladies and gentlemen, to present the President of the United States, President Bill Clinton.

THE PRESIDENT: Thank you very much. The whole issue of climate change must be looked at in terms of our deepest obligations to future generations. I have spent most of my time in the last 4½ years trying to prepare the American people for a new century and a new millennium. We must also protect the Earth for that new millennium, to ensure that the American people will benefit from the opportunities we are trying to create. We cannot

fulfill our responsibilities to future generations unless we deal responsibly with the challenge of climate change.

The overwhelming balance of evidence and scientific opinion is that it is no longer a theory, but a fact, that global warming is for real. The world's scientists believe

"We have the evidence, we see the train coming, but most ordinary Americans in their day-to-day lives can't hear the whistle blowing"

— President Bill Clinton

that if we don't cut our emissions of greenhouse gases, we will disrupt the global climate.

In the face of this, the United States must confront a challenge that in some ways is the most difficult of all democracy's challenges. We have the evidence, we see the train coming, but most ordinary Americans in their day-to-day lives can't hear the whistle blowing. Unless they have lived in a place where they have experienced severe and completely atypical weather in the last five years or so, the degree of the challenge is inconsistent with the actual perceived experience of most ordinary Americans.

A democracy is premised on the proposition that, if the American people or any people in any democracy know what the facts are and believe them, way more than half the time they will do the right thing. So what we are doing today is beginning a process in which we ask the American people to listen to the evidence, to measure it against their own experience, but not to discount the weight of scientific authority if their own experience does not yet confirm what the overwhelming percentage of scientists believes to be fact today.

I do want to say that I am convinced that, when the nations of the world meet in Kyoto, Japan, in December on this issue, the United States has got to be committed to

realistic and binding limits on our emissions of greenhouse gases. Between now and then we have to work with the American people to get them to share that commitment. We have to emphasize flexible, market-based approaches. We have to embrace research and development efforts in technology that will help us to improve the environment while permitting our economy to grow. We have to ask all nations, both industrial and developing, to participate in this process. If we do this together, we can defuse this threat, and we can make the 21st century what it ought to be, not only for our children, but for all the children of the world.

I believe the science demands that we face this challenge now. I'm positive that we owe it to our children. And I hope that we can find the wisdom and the skill to do democracy's work in the next few months to build the consensus necessary to actually make action, as opposed to rhetoric, possible. To all of you, for your commitment to that, I thank you.

And now I'd like to ask Dr. Rowland to be the first of our distinguished scientists to lead off.

DR. ROWLAND: Mr. President and Mr. Vice President, global climatic change is underway. Carbon dioxide from the combustion of coal, oil, and natural gas has risen 15 percent in the atmosphere since 1958. Methane, some of which is emitted from cattle and rice paddies, has increased 16 percent since 1978. The air now holds four

times as much chlorofluorocarbons as it did 25 years ago. The amount of ozone in the stratosphere over the United States is 6 to 10 percent lower than it was in the 1960s.

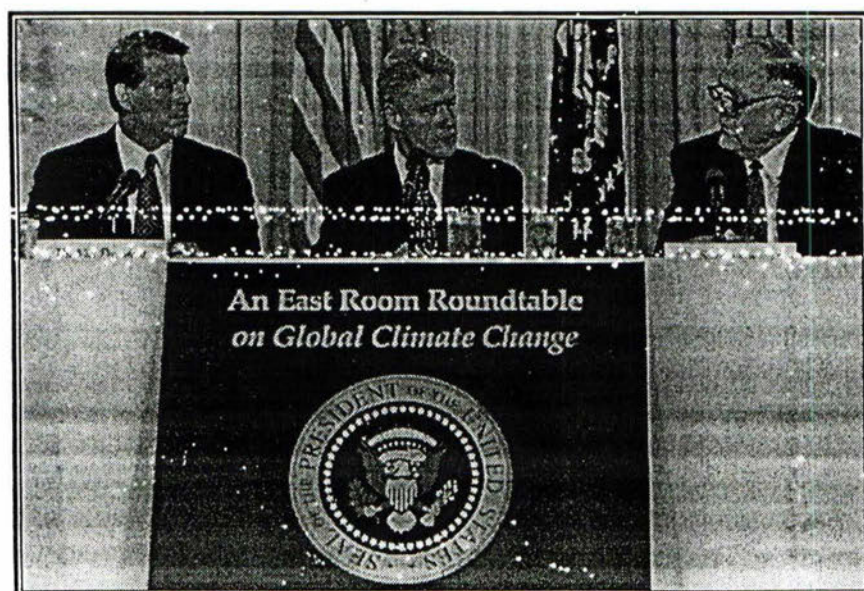
"Mr. President and Mr. Vice President, global climatic change is underway."

— F. Sherwood Rowland

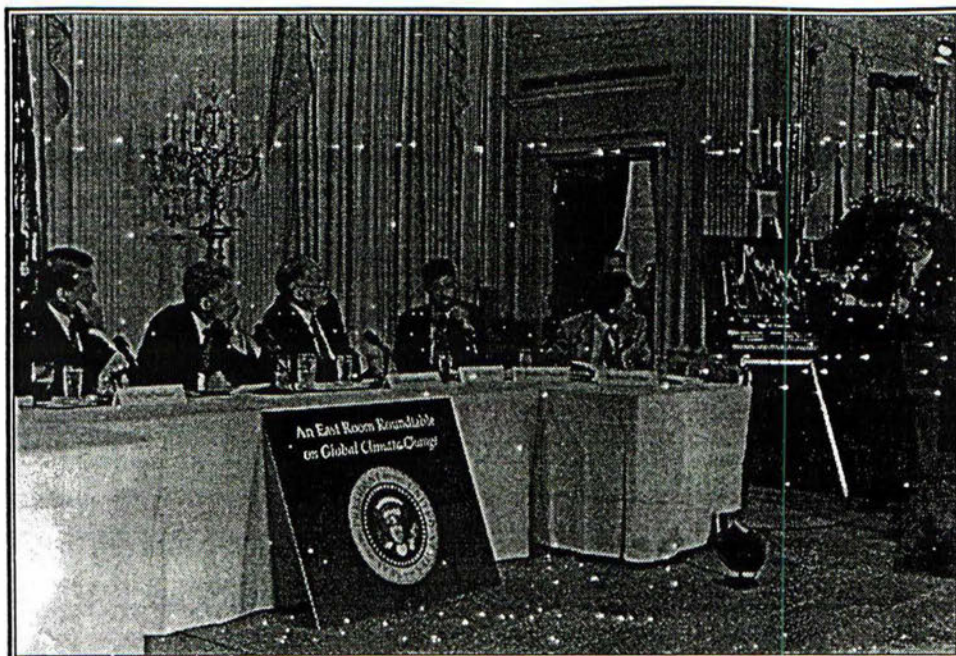
Many other changes are occurring as well. The global average surface temperature has risen about 1 °F during the past century, and sea level has risen from 4 to 10 inches.

Land use patterns have been greatly altered as forests are burned for use as agricultural land. Many of the species formerly in these forests are disappearing. The geographical ranges of tropical diseases are moving northward. Human activities are the chief cause of many of these changes. The last century saw tremendous growth in the global population, from about 1½ billion in 1900 to 6 billion in the year 2,000 and 8 billion in the year 2025. Much of the world is now moving as fast as possible into a more affluent, energy-intensive era.

The combination of a rapidly growing world population with an increase in per capita use of energy carries with it great pressures on the environment and the atmosphere. Because the wind circles the earth within a few weeks, greenhouse gases emitted from each country quickly



Expert climate scientists from more than 50 countries agree that "the balance of evidence suggests that there is a discernible human influence on global climate." Dr. F. Sherwood Rowland, Nobel Prize recipient, noted that global temperature records indicate an overall warming of about 1 °F over the last century.



Due to human activities — primarily the burning of fossil fuels — atmospheric concentrations of several greenhouse gases have substantially increased since the beginning of the Industrial Revolution. Dr. Mario Molina, Nobel Prize winner, noted that current projections indicate atmospheric concentrations will exceed 700 parts per million by 2100. This would be the highest level of carbon dioxide in the atmosphere in 50 million years.

More than 2600 scientists have now signed a statement on global climatic disruption in which, as scientists and as concerned citizens, we ask that the United States demonstrate strong leadership in the global effort with a firm proposal for reducing U.S. emissions of greenhouse gases.

— F. Sherwood Rowland

become a global problem requiring a global solution. During the 1990s, the world called upon its scientists to evaluate the question of global warming from the accumulation of greenhouse gases. The authoritative IPCC has estimated a probable increase in global surface air temperature of about $3\frac{1}{2}$ °F by the year 2100, with a possible range from 2 to $6\frac{1}{2}$ °F. They further stated that the balance of the evidence suggests a discernible human influence on global climate, and warned that the average rate of warming will probably be greater than any experienced in the past 10,000 years. The variation in estimated outcomes depends upon what the countries of the world do to control the emissions of carbon dioxide and other greenhouse gases in the intervening years. More than 2600 scientists have now signed a statement on global climatic disruption in which, as scientists and as concerned citizens, we ask that the United States demonstrate strong leadership in the global effort with a firm proposal for reducing U.S. emissions of greenhouse gases.

THE VICE PRESIDENT: Now I'd like to ask Dr. Mario Molina to give us an overview of the science of climate change.

DR. MOLINA: I'd be pleased to do that, Mr. Vice President. The "greenhouse effect" is a process that affects the heat patterns of our planet. The earth receives energy from the sun, which passes relatively freely through the atmosphere. But the energy that the earth emits back to outer space is actually trapped by certain gases in the earth's atmosphere, which affects the earth's heat patterns. One of these gases is carbon dioxide, which is the most important greenhouse gas. And what we have in the figure is a representation of the amount of carbon dioxide in the atmosphere going back in time 160,000 years. The levels of carbon dioxide range between about 190 and 280 parts per million. We know this from measuring the composition of air bubbles trapped in ice cores from Antarctica and Greenland. The lower curve in the figure is a similar record of temperature going from the present back 160,000 years. There is a remarkably large correlation between these two curves. You can see that the preindustrial amounts of CO₂ are below 300 parts per million. The current concentration of CO₂ is roughly 365 parts per million. What is striking is that this is a level that we haven't seen before, certainly not in the past 160,000 years, and we got there very fast.

The next question is where are we heading? What happens in the future depends on what we do. If we continue with the so-called "business-as-usual" scenario,

"If we continue with the so-called 'business-as-usual' scenario, we can predict that we are going to reach levels of about 700 parts per million. And what is remarkable is how fast this would occur — in only the blink of an eye on the geological or evolutionary time scale."

— Mario Molina

we can predict that we are going to reach levels of about 700 parts per million. And what is remarkable is how fast this would occur — in only the blink of an eye on the geological or evolutionary time scale. I should point out that the earth has actually seen such high levels of carbon dioxide in the past, but that was some 50 million years ago when the earth was a very different place from what it is now.

This is the sort of evidence that makes the scientific community consider this to be a serious problem. The magnitude and the pace of change are what make us really worry.

THE PRESIDENT: Thank you very much. Now, I'd like to call on Dr. Jane Lubchenco, our expert on ecology, and see what such significant changes in greenhouse gas levels might mean for natural resources.

DR. LUBCHENCO: Mr. President, Mr. Vice President, as both of you are aware, the ecological systems of the world — the forests, wetlands, coral reefs — provide the life support systems for all of life on earth. Important ecosystem functions, including flood control, purification of air and water, and the creation of beautiful places for recreation and inspiration can only be provided by intact ecological systems, and when those systems are disrupted or lost, then we lose the goods and services they provide. To provide a few vignettes of the ecological consequences of climate change, in the optimistic scenario of a doubled CO₂ world, let me invite you on a brief field trip to different parts of our country:

- Let's begin in the forests of New England, which like probably a third of the forests around the globe, will undergo major changes. For example, we would probably lose sugar maples from the New England forests.
- Let's move to the southern part of our country. Salt marshes in Louisiana are already being submerged. Climatic change would exacerbate this problem as sea



Natural ecosystems will shift as individual species respond to changes in climate. Rates of temperature change over the next century are expected to be faster than have been observed over the last 10,000 years. Dr. Jane Lubchenco predicted this will lead to loss of biological diversity and the services ecosystems provide for society, estimated to be worth trillions of dollars annually.



Human health and food security may be adversely affected by climate change. In combination with increasing populations and limited land and water resources, climate change is likely to lead to increased pressures on food supplies and disease surveillance systems.

level rises between six inches and three feet. The loss of salt marshes would result in the loss of nursery areas, which are the natural hatcheries for important fish and shellfish. We would also lose the system's ability to detoxify pollutants, trap sediments, create a habitat for unique plants and animals, and protect the shores against the battering of waves.

- Now let's move to the Midwest. Drought is no stranger to this region. The heat wave in 1988 resulted in a one-third drop in U.S. agricultural production. While these highly managed agricultural systems are thought to be quite adaptable, climate change is likely to increase demands on available water to ameliorate soil drying, and on pesticide use to combat increased incidences of pests and diseases.
- Flying up to Glacier National Park in Montana, we would be dismayed to find out that fully 73 percent of the glacial areas have already been lost since 1850 because of climate warming. In fact, climate change is predicted to result in loss of all of the glaciers in the park by the year 2030, well within many of our children's lifetimes.

As an ecologist, I must emphasize that the slower the rate of change in climate, the less catastrophic the results. Species are more likely to be able to migrate, to grow, and evolve if the rate of change is slow.

"The slower the rate of change in climate, the less catastrophic the results. Species are more likely to be able to migrate, to grow, and evolve if the rate of change is slow."

— Jane Lubchenco

Climate change is only one of many environmental changes occurring around the world today. There are multiple stresses, including familiar things like urbanization, over-fishing, pollution, and the loss of biological diversity. Taken together, these stresses are reducing the ecosystems that we depend upon for our quality of life. As a scientist, I know enough to appreciate how serious and urgent the problem of climate change is. As a mother, I care especially about the prospects of the world that my children will inherit. I do not wish them to have a world that is disrupted and depauperate. The quality of their future depends upon our willingness to act and to act quickly.

THE VICE PRESIDENT: Thank you. Let me call now on Dr. Steve Schneider to discuss the risks of severe or extreme weather events — droughts, floods, and hurricanes — which have been predicted to accompany global warming.

DR. SCHNEIDER: Thank you very much, Mr. Vice President, Mr. President. What we're addressing at the moment is, "so what if the climate changes?" This is a question that scientists have spent a long time on, doing literally hundreds of studies, suggesting outcomes ranging from catastrophic to mild. Let's take a look at just two examples — the sea level question and the question of hydrologic extremes, droughts and floods. We all remember the terrible pictures from hurricane Andrew, which resulted in losses on the order of \$40 billion in Florida and other areas around the Caribbean. Could we have had something to do with that? If you increase the temperature of the oceans, it increases evaporation, it might make storms stronger. That's very controversial. But one thing we know that isn't controversial is that before 1987 there were no losses larger than \$1 billion. And now the insurance industries are very concerned that there have been several in the tens of billions.

What else do we know that's not controversial? Sea levels have gone up and are projected, typically, to go up six inches to maybe three feet, depending upon how things turn out in the next century. And whether storms are augmented in strength by global warming or remain at their natural levels, they'll be causing flooding from a higher sea-level base. As a result of that, the damages would go further inland.

What about the hydrologic extremes? Well, we all saw pictures of the 1988 drought. We know about the seemingly endless stories of floods now. And the question is, "Has nature rolled us a double snake eyes, or have we started to load the dice?" Again, physics says if you increase the heating of something that has water in it, more water will evaporate. So, what that suggests is that more water in the air means that when it does rain, the rainfall can be more intense. When it's dry, you can have more evaporation.

"What about the hydrologic extremes? Well, we all saw pictures of the 1988 drought. We know about the seemingly endless stories of floods now. And the question is, 'Has nature rolled us double snake eyes, or have we started to load the dice?'"

— Stephen Schneider

The question is, what's happening? A line that we often use in science is, well, in God we trust, but for the rest of us, please show data. Dr. Tom Karl and his colleagues in North Carolina, for example, have concluded that there has been about a 10 percent increase in precipitation across the United States since 1910. The interesting part,

"So, while no one event certainly could be laid to the doorstep of global warming, the increasing frequency and magnitude of severe storms could very well be the first signs of the canary in the cage starting to quiver."

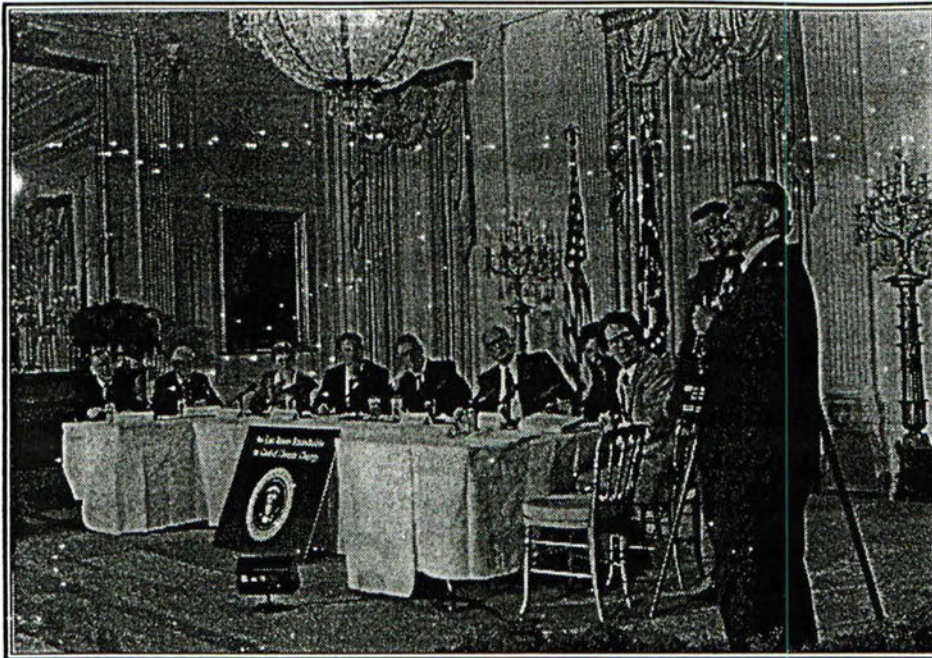
— Stephen Schneider

as Tom says, is, "The increase in precipitation is reflected primarily in the heavy and extreme daily events." Translated: Gully washers. The bulk of the rainfall increase has been in those kinds of damaging, extreme events. A pattern is emerging, and the pattern is consistent with the expectations from our models. So, while no one event certainly could be laid to the doorstep of global warming, the increasing frequency and magnitude of severe storms could very well be the first signs of the canary in the cage starting to quiver.

The IPCC concluded with a paragraph I know well as a lead IPCC author, and I'll quote what it said in its last paragraph of the summary for policy makers. "When rapidly forced, nonlinear systems are especially subject to unexpected behavior." In my words, that means reducing the pressures humans put on nature is insurance against potential nasty surprises.

THE PRESIDENT: Thank you very much. Now, I'd like to ask Dr. Robert Shope, who studies infectious diseases extensively, to discuss how human health might be affected by climate change.

DR. SHOPE: Thank you, Mr. President. Health and the environment are closely linked. If there is a 6 °F warming, the heat alone in North American cities, such as Washington, D.C., will result in an excess of deaths, especially in elderly people who do not adapt well to severe warmth. We had an



Mankind has dramatically altered the composition of the atmosphere in the last 150 years. The concentration of carbon dioxide is 30 percent higher than it was in 1860 and is now higher than it has been in 160,000 years.

example in July of 1995 in Chicago, Illinois. There the temperature exceeded 90 °F night and day for a prolonged period, and there were 465 deaths recorded in Chicago related to the heat.

My own personal experience is with diseases transmitted by ticks, mosquitoes, and other biting insects. Let me talk about dengue virus. This causes a disease in people which typically gives them high fever, headache, muscle aches and pains, and sometimes a rash. There is a more severe form of dengue, dengue-hemorrhagic fever, in which the case mortality rate is about 10 percent. This virus is transmitted by a mosquito that lives in and around homes in warm climates. The mosquito is killed by a hard freeze; therefore, its northern limit is about Memphis, Tennessee, at the present time. In the last decade, we've seen a steady increase in the numbers of cases of dengue in tropical America, including Mexico. This disease is now literally on our southern border. I cannot tell you whether dengue epidemics will occur in the United States, but with climate change and warming, the mosquito will thrive further north.

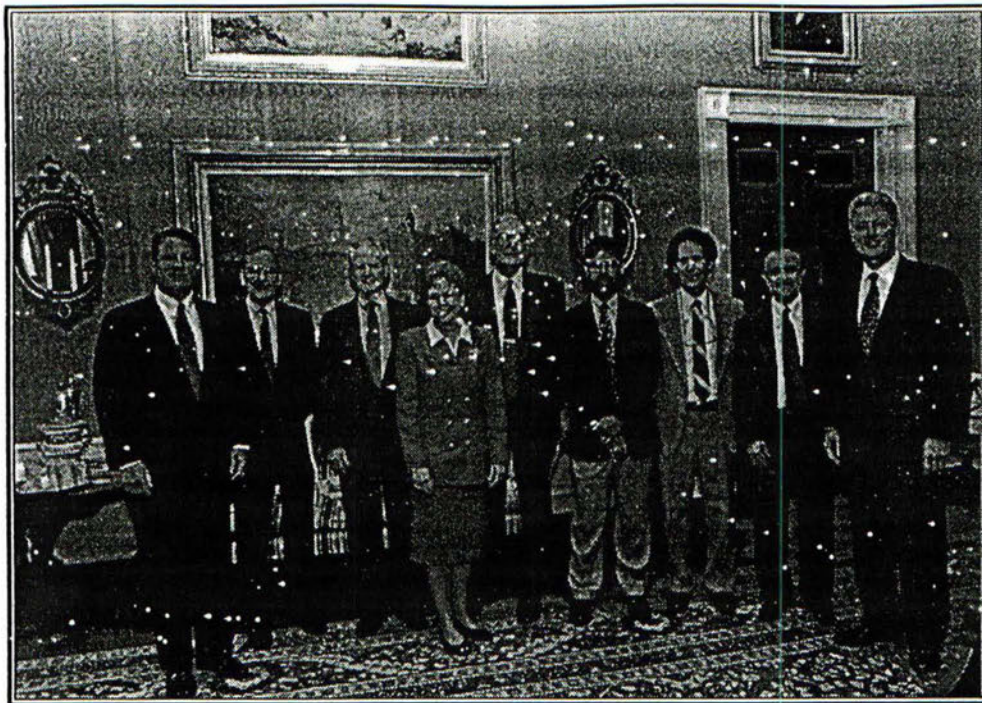
These same factors apply to the vector of malaria, also a mosquito. Malaria is a disease that, worldwide, kills approximately 2 million people each year. It's a tropical disease, but recently has occurred in small outbreaks in the United States, in New Jersey, New York, and Texas, and

with warming we can expect these outbreaks to continue and to enlarge.

"Malaria is a disease that, world-wide, kills approximately 2 million people each year. It's a tropical disease, but recently has occurred in small outbreaks in the United States, in New Jersey, New York, and Texas, and with warming we can expect these outbreaks to continue and to enlarge."

— Robert Shope

The factors that I've talked about argue for controlling the environment while we still have time, and I will say that the best insurance is preparedness. There are many other diseases directly affected by rainfall and warming — St. Louis encephalitis, the tick-borne Lyme disease, and the newly recognized rodent-associated Hantavirus pulmonary syndrome, which broke out in 1993 in the southwestern part of the United States. Each nation in the world has its own set of diseases, some of which affect Americans abroad or can be transported and introduced into the United States. Therefore, the problem of climate change and health is of common interest among nations as are the solutions. Thank you.



The vast majority of the world's leading climate experts are concerned that human-induced climate change could have profound consequences for the economy, human health, and quality of life in future generations. Flanked by the Vice President and the President, the eminent U.S. scientists who contributed to the White House roundtable discussion of climate change are (left to right) Robert Shope, Henry Kendall, Jane Lubchenco, F. Sherwood Rowland, John Holdren, Stephen Schneider, and Mario Molina.

THE VICE PRESIDENT: All right. I'd like to ask Dr. Henry Kendall, Nobel laureate and chairman of the Union of Concerned Scientists to speak to the international dimensions of the issue.

DR. KENDALL: Mr. President, Mr. Vice President, thank you for this opportunity. Disruption of the climate is linked to, and can aggravate, many other human problems. One link I'd like to talk about is the connection with world food production. Agriculture, as is widely recognized, needs a stable climate in order to be highly productive. But in 1988, in the central North American continent, with combined high temperatures and drought, both Canada and the United States lost one-third of their grain supplies. For the first time in 200 years, food production was not adequate to feed us. In the years since, Australia and Mexico have had somewhat similar events.

Food demand is expected to double in the next 30 years, which is almost no time at all. Fresh water, which is vital

for irrigation, is already short. The human race uses nearly one half of the available fresh water, and 40 percent of the world's population lives in areas that are water short.

"It is not the case that one end of the boat can sink, so let me say that this is a developing problem in national security, and we have to deal with it."

— Henry Kendall

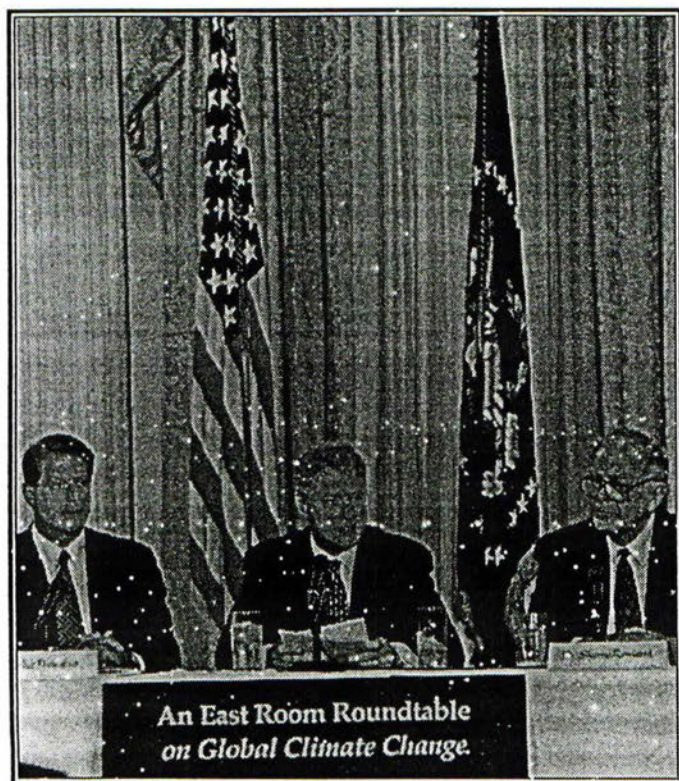
"No nation will be sheltered from the effects of dislocations in food supplies, altered trade balances, and fresh water difficulties."

— Henry Kendall

Expansion into new arable land is highly constrained, and the last thing we need are climatic changes and disruptions putting additional pressures on a system that is already becoming considerably stressed. Of course, it's the bottom tier of the developing nations that will get hit directly by shortages. This has already started to generate increasing numbers of hungry migrants, environmental refugees, streaming across national borders. The result is that no nation will be sheltered from the effects of dislocations in food supplies, altered trade balances, and fresh water difficulties. The flow of migrants may increase into the hundreds of millions of people. And even though the wealthy nations will remain able to feed themselves, and remain well fed into the future, no nation will escape troubles from pressures on the food supply. Mr. President, it is

not the case that one end of the boat can sink, so let me say that this is a developing problem in national security, and we have to deal with it. The best way to deal with problems of this sort is to stop them at the outset and not wait until the results are presented to us and the great troubles have developed. Thank you.

THE PRESIDENT: Thank you. I'd like to now turn to Dr. John Holdren, who's worked on many global issues. Why do you think people are underrating the importance of the climate change issue, and what do you think we can do about it?



Climate change is a global issue requiring a global response. President Clinton has stated that "we have to ask all nations, both industrial and developing, to participate in this process. We have to emphasize flexible, market-based approaches. We have to embrace research and development efforts in technology that will help us to improve the environment while permitting our economy to grow. If we do this together, we can diffuse this threat, and we can make the twenty-first century what it ought to be, not only for our children, but for all the children of the world."

DR. HOLDREN: I think, Mr. President, Mr. Vice President, there are at least six reasons why most people underrate the seriousness of the climate disruption problem. I think the first reason that people tend to underrate this problem is that human well-being is a lot more dependent on climate than most people think. As you heard today, we're talking about the productivity of farms and forests and fisheries. We're talking about the frequency and intensity of floods and droughts and heat waves. We're talking about the geographic pattern of disease. We're talking about sea level rise and associated destruction of coastal property. And we're talking about the potential for political tension and conflict over the consequences and over who's responsible and who should pay.

The second reason people tend to underrate this problem is that climate disruption is a lot further along than most people think. As we've seen, atmospheric carbon dioxide is already higher than it's been in the last 160,000 years. The global surface temperature, which is expected to lag behind increasing carbon dioxide concentration, is higher than it's been in the last thousand years.

The third reason that many people are more complacent than they should be is that the climate implications of future growth in population and future growth in energy consumption are a lot bigger than most people think. We're going to have in the year 2050, barring near disaster, something like 9 billion people compared to less than 6 billion today. We're going to have energy use under "business as usual" that will be three times higher than today's and CO₂ emissions that are 2 to 2½ times today's worldwide.

The fourth point is that scientific uncertainties are not grounds for complacency, in spite of what many people may think. There are uncertainties about many of the details of timing and magnitude and regional variation in the consequences of climate change, but there is no uncertainty at all that humans have significantly altered the global atmospheric concentrations of gases we know to be critical in controlling climate. And there's a solid consensus among the scientists who have studied these matters seriously that the chances of significant impacts on human well being from climate change over the next few decades are substantial.

The fifth reason that people underrate the problem is that the time lags between cause and effect and between effect and remedy are longer than most people think. Those time lags and above all the several decades that it will take to substantially successfully transform the world's fossil fuel-dependent energy supply system mean that doing nothing is a very dangerous course of action. The world's energy-economic system is a lot like a supertanker, very hard to steer and with very bad brakes, and we know from the science that has been reviewed here today that that supertanker is heading for a reef. Even though we can't say exactly when we're going to get to the point where that reef rips the bottom out of the supertanker, it's a bad idea in these circumstances to keep on a course of full speed ahead.

"The world's energy-economic system is a lot like a supertanker, very hard to steer and with very bad brakes, and we know from the science that has been reviewed here today that that supertanker is heading for a reef."

— John Holdren

The last reason that people tend to underrate this problem is because the fate of industrialized and less developed countries is a lot more interconnected than most people think. We all live on this planet under one atmosphere. We all live on the shores of one global ocean. Our countries are linked by flows of people, money, goods, ideas, images, drugs, and weapons. If we in the industrialized countries are to enjoy a stable and sustainable prosperity, we are only going to be able to manage that if we can achieve for the rest of the world now less fortunate a stable and sustainable prosperity as well. And the only way to do that is going to include addressing the danger of global climate disruption in a cooperative way.

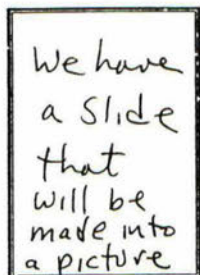
"We all live on the shores of one global ocean. Our countries are linked by flows of people, money, goods, ideas, images, drugs, and weapons. If we in the industrialized countries are to enjoy a stable and sustainable prosperity, we are only going to be able to manage that if we can achieve for the rest of the world now less fortunate a stable and sustainable prosperity as well. And the only way to do that is going to include addressing the danger of global climate disruption in a cooperative way."

— John Holdren

THE VICE PRESIDENT: Thank you.

THE PRESIDENT: I wish every American could hear what we've heard today. This is the beginning of a consistent, long-term effort that we all have to make to involve the people of this country in this decision. And I thank you all for the points you've made because in different ways each of them will resonate with citizens of this country in a way that I believe will give us the support we need to take the action that has to be taken. In the weeks and months ahead, the Vice President, the Cabinet, other members of the Administration, and I will be out in the country discussing this. We will be working with the American people. We will be talking about solutions as well as problems.

Biographies



Dr. F. Sherwood Rowland
(Nobel Laureate in Chemistry, 1995,
Professor at University of California, Irvine,
Foreign Secretary for the National Academy
of Sciences, Past President of the American
Association for the Advancement of Science)

In 1995, Sherwood Rowland, along with two of his colleagues, won the Nobel Prize in Chemistry for pioneering research in atmospheric chemistry of the destruction of the ozone layer. Since receiving his Ph.D. from the University of Chicago in 1952, he has climbed the academic ranks in chemistry, and is currently the Donald Bren Research Professor of Chemistry and Earth System Science at the University of California at Irvine. Dr. Rowland has received many awards including the Roger Revelle Medal from the American Geophysical Union. He also currently serves as the Foreign Secretary of the National Academy of Sciences, and is a former President and Chairman of the Board of the American Association for the Advancement of Science.



Dr. Mario Molina
(Nobel Laureate in Chemistry, 1995,
Professor at Massachusetts Institute of
Technology, Member of the President's
Committee of Advisors on Science and
Technology)

Mario Molina was awarded the Nobel Prize along with Sherwood Rowland for research on the thinning of the ozone layer. Dr. Molina and his colleagues demonstrated experimentally how ozone-destroying chlorine functions in the atmosphere. He is currently the Lee and Geraldine Martin Professor of Environmental Science at Massachusetts Institute of Technology. Since completing his Ph.D. in physical chemistry at the University of California, Berkeley, Dr. Molina has received many honors and awards, including election to the National Academy of Sciences, and selection as a Pew Scholar on Conservation and the Environment. He has also served as an advisor to the National Aeronautics and Space Administration, the National Science Foundation, and the National Institutes of Health.



Dr. Jane Lubchenco
(Professor at Oregon State University, Past
President of both the American Association
for the Advancement of Science and the
Ecological Society of America)

Jane Lubchenco is currently the Wayne and Gladys Valley Professor of Marine Biology and Distinguished Professor of Zoology at Oregon State University, and has been awarded a litany of honors. She has been selected as a Pew Scholar in Conservation and the Environment, a MacArthur Fellow, a member of the National Academy of Sciences, and a member of the National Science Board. She is also an American Academy of Arts and Sciences Fellow, an American Association for the Advancement of Science Fellow, and has received numerous teaching awards. She has accomplished all of this since receiving her Ph.D. from Harvard University in 1975.



Dr. Stephen Schneider
(Professor at Stanford University,
MacArthur Fellowship, the American
Association for the Advancement of Science
Westinghouse Award for Public
Understanding of Science and Technology)

After receiving his Ph.D. in Mechanical Engineering and Plasma Physics from Columbia University in 1971, Stephen Schneider focused on the influence of greenhouse gases and suspended particles on the earth's climate as a postdoctoral researcher at NASA's Goddard Institute for Space Studies, and later at the National Center for Atmospheric Research, where he remained until 1996. In 1992, Dr. Schneider was awarded a MacArthur Fellowship for his ability to integrate and interpret the results of global climate research through public lectures, seminars, media appearances, and research. He was also honored with the American Association for the Advancement of Science Westinghouse Award for Public Understanding of Science and Technology for his ability to express environmental science and its implication for public policy to the general public. Currently he is a Professor in the Department of Biological Sciences and a Senior Fellow at the Institute for International Studies at Stanford University.

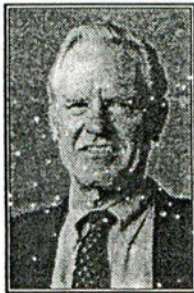


*Dr. Robert Shope
(Professor at University of Texas, Director of
the Yale Arbovirus Research Unit for 24 years)*

Robert Shope has devoted his career to the study of viruses carried by mosquitoes, ticks, and other biting insects. These viruses can cause life-threatening diseases in humans such as malaria, dengue and yellow fevers, and encephalitis. Since receiving his medical degree in 1954 from Cornell University, he

has spent many years in Malaysia, Brazil, and other tropical sites studying these insect-borne diseases. He was a Professor of Epidemiology at Yale University's School of Medicine from 1975 to 1995, and served as the Director of the Yale Arbovirus Research Unit. During that period he was awarded many honors, including the Walter Reed Award from the American Society of Tropical Medicine and Hygiene. He is presently a Professor in the Departments of Pathology and Microbiology and Immunology at the University of Texas Medical Branch.

Dr. Henry Kendall



*(Nobel Laureate in Physics, 1990,
Professor at Massachusetts Institute of
Technology, Chairman of the Board of the
Union of Concerned Scientists)*

In 1990, Henry Kendall won the Nobel Prize in Physics, along with two colleagues, for his insightful work in particle physics. Dr. Kendall is currently the J.A. Stratton Professor of Physics at the Massachusetts

Institute of Technology. He also serves as the Chairman of the Board of the Union of Concerned Scientists, an organization which he helped found in 1994. Throughout his career, Dr. Kendall has focused on U.S. energy and defense issues such as the nuclear arms race, nuclear power, and renewable energy. He has many other awards and honors including being elected to the National Academy of Sciences.



*Dr. John Holdren
(Professor at Harvard University, member of
the President's Committee of Advisors on
Science and Technology)*

John Holdren is a world-renowned expert on energy and environmental science. In 1995, he delivered the Nobel Peace Prize acceptance lecture on behalf of the Pugwash Conferences, on the occasion of that organi-

zation's sharing of the 1995 prize. He is currently the Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy in the John F. Kennedy School of Government, and Professor of Environmental Science and Public Policy in the Department of Earth and Planetary Sciences at Harvard University. From 1973 to 1996, he was a Professor of Energy and Resources at the University of California at Berkeley. He has been elected ...a Fellow of the National Academy of Sciences, the American Physical Society, the American Association for the Advancement of Sciences, the California Academy of Sciences, and the American Academy of Arts and Sciences. He was also awarded the MacArthur Foundation Prize. Dr. Holdren received his Ph.D. from Stanford University in aeronautics, astronautics and theoretical plasma physics in 1970.

DRAFT -- DO NOT QUOTE OR CITE

Thoughts on Climate:

We need to look at this issue with a long-term as well as short-term perspective, with a focus on where we have been, an assessment of where we are going, and a decision on the course we need to chart to arrive at an environmentally desirable destination.

Keep in mind through the following that many emissions scenarios only consider carbon dioxide. Non-CO₂ greenhouse gases such as methane (CH₄) and nitrous oxide (N₂O) make the “effective” atmospheric concentrations about 20% higher than they would be with CO₂ alone.

1. Where have we been:

- pre-industrial levels and current levels of greenhouse gas concentrations in the atmosphere:

	CO ₂	CH ₄	N ₂ O
Pre-industrial	280 ppm	700 ppb	275 ppb
Current	360 ppm	1720 ppb	312 ppb

- who has been responsible for what is now in the atmosphere?
 - Developed world: 80% of CO₂ = 25% from FSU & EE + 55% from OECD
 - Developing world: 20% of CO₂
- current list of top 10 countries in terms of total emissions:

	Country	emissions (in thousands of metric tonnes C)
1	United States	1387256
2	China (Mainland)	828436
3	Russian Federation	440979
4	Japan (73-)	303267
5	India	236448
6	Germany	219612
7	United Kingdom	149741
8	Canada	121712
9	Ukraine	111644
10	Italy (including San Marino)	106947

2. Where are we going:

- all the impacts work we have relates to a doubling of concentrations:

- There will be significant changes in water availability nationwide. Additionally, the frequency and intensity of floods and droughts will change. In the United States, the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande, and Lower Colorado River Basins are likely to be most vulnerable.
 - One-third of the Earth's forests could undergo a major change in vegetation: the Northeast United States will likely lose beech trees and sugar maples. Western conifer forests will decrease in area.
 - A sea level rise of 20 inches is expected over the next century. This could inundate more than 5000 square miles of dry land and an additional 4000 square miles of wetlands. The Atlantic and Gulf Coasts are particularly vulnerable.
 - There will be significant shifts in the ideal range for many agricultural crops. Food scarcity may increase, especially in the tropics and sub-tropics.
 - Heat-related mortality and illness will increase. Reduced air quality will exacerbate respiratory disease, asthma, and allergic disorders.
 - Geographic ranges for disease will expand, leading to an increase in diseases such as malaria, dengue and yellow fever. 50-80 million additional cases of malaria per year are projected worldwide.
- If we choose an objective that is greater than a doubling of CO₂ concentrations, we are essentially in uncharted waters; we know the impacts will be greater, but we do not know how much greater. (At about 4XCO₂, photosynthesis appears to cease in plants.)
 - So let's look at some scenarios to achieve 450 ppm, 550 ppm, 650 ppm, keeping in mind the need for the developed countries to take the lead, but the obvious fact that the developing countries need to participate.

To reach a concentration goal of	<i>world</i> emissions must deflect off BAU by	and peak in	at
450 ppm	2007	2011	8.0 PgC/yr
550 ppm	2013	2033	9.7 PgC/yr
650 ppm	2018	2049	11.4 PgC/yr

- If Annex I countries freeze emissions in 2010 at 1990 levels and then steadily decline (at 2.5%/decade-7.5%/decade), then

To reach a concentration goal of	<i>developing country</i> emissions can exceed BAU until	and must peak in
450 ppm	2015	2012
550 ppm	2030	2040-2050
650 ppm	2060	2058-2068

- Per capita reality check:

- If Annex I countries freeze emissions in 2010 at 1990 levels and then steadily decline (at 2.5%/decade-7.5%/decade):

<i>Developed</i> country per capita annual emissions are currently	A scenario with concentration goals of	shows per capita emissions changing by 2100 to
~3.5 Tonnes C/person	450, 550, & 650 ppm	1.5-2.5 Tonnes C/Person

<i>Developing</i> country per capita annual emissions are currently	A scenario with concentration goals of	shows per capita emissions changing by 2100 to
~.4 Tonnes C/person	450 ppm	less than .2 Tonnes C/Person
~.4 Tonnes C/person	550 ppm	~.4 Tonnes C/Person
~.4 Tonnes C/person	650 ppm	.7 Tonnes C/Person

Revised 8/27/97 climate
as per your suggestions, Brochure
Rosina

Climate Change: State of the Knowledge Brochure

Covers:

Front: Earth picture (maybe one that shows how thin the atmosphere is)
Title

Inside: Text on climate change research programs: USGCRP, IPCC, IGBP, etc.

Back: Biosphere (the Living Earth)

Body:

Opening (abstract)

The Greenhouse Effect and Historical Emissions

Climate Change Over the Last 100 years

Climate Change Over the Next 100 years

Vulnerabilities and Potential Consequences

Opening (“Abstract”)

The Intergovernmental Panel on Climate Change stated that the balance of the scientific evidence now suggests that there is “a discernible human influence on global climate.” The Earth’s climate system is already experiencing rates of change faster than any during the last 10,000 years, the period in which modern civilization developed. The Panel estimated that an increase in global surface air temperature of about $3\frac{1}{2}^{\circ}\text{F}$ is likely by the year 2100, although the change could be as low as 2 and as high as $6\frac{1}{2}^{\circ}\text{F}$, depending on what the countries of the world do to control their emissions of carbon dioxide (CO_2) and other greenhouse gases in the intervening years.

The ultimate aim of the Framework Convention on Climate Change is to stabilize greenhouse gas concentrations “at a level that would prevent dangerous anthropogenic interference with the climate system.” This level should be achieved within a time frame that (1) allows ecosystems to adapt naturally to climate change, (2) ensures that food production is not threatened, and (3) enables sustainable economic development to proceed. While much work remains to be done to improve the precision of impact assessments, the risks of climate change are becoming increasingly apparent, and lend support for the idea that measures for mitigation and adaptation are warranted.

The Greenhouse Effect and Historical Emissions

Life as we know it is possible on Earth because of a natural greenhouse effect that keeps our planet about 60°F warmer than it otherwise would be. (Figure 1) Water vapor, carbon dioxide (CO₂), and other trace gases, such as methane and nitrous oxide, trap heat and keep it from being lost by re-radiation back to space. With industrialization, the amounts of greenhouse gases added to the atmosphere by human activities have begun to exert significant influence. Although these amounts are small relative to the total CO₂ content of the atmosphere, the steady additions are tipping a delicate balance. On a global scale, burning of coal, oil, and natural gas releases about 6 billion tons of carbon into the atmosphere each year. Land-use change, predominantly the clearing of forests for agriculture, contributes about 1-2 billion tons more per year globally. (Figures 2 and 3) Consequently, greenhouse gas concentrations in the atmosphere are steadily increasing.

Since 1860, CO₂, the most important human-derived greenhouse gas, has increased 30%, from 280 to 360 parts per million (ppm) (Figure 4). Methane concentration has also more than doubled, and nitrous oxide has risen by 15%.

Over a much longer time scale, there is a clear relationship between CO₂ levels and the global temperature record. Fluctuations of CO₂ and temperature have closely mirrored each other over the last 160,000 years. (Figure 5)

Whose emissions are in the atmosphere? In 1990, 74% of total CO₂ emissions came from the developed countries, with the United States the largest single source (22% of total). (Figure 6). Over the next few decades, 90% of the world's population growth will take place in the developing countries. If current trends continue, the developing countries will account for half of total global emissions by 2035. By that time, China, which has already become the second largest source, will displace the U. S. as the largest emitter. Per capita energy use in the developing countries, which is currently only 1/10 to 1/20 of our level, will also increase.

Climate Change Over the Last 100 years

What has happened to date? The Intergovernmental Panel on Climate Change's Second Assessment Report in 1995 described a series of changes that have already been observed. Over the last century, the average surface temperature of the Earth has increased by about 0.5 - 1.0 °F to a level that is as high or higher than it has been in any century since at least 1400 AD. The eleven warmest years this century have all occurred since 1980, with 1995 the warmest on record. (Figure 7) The higher latitudes have already warmed even more.

Critics have noted that the long term surface temperature and the short term satellite observations of the atmosphere do not match exactly. Global surface temperature has been measured since 1880 at a network of ground-based and ocean-based sites. Beginning in 1979, satellites have also been used to measure the temperature of the atmosphere up to a height of 30,000 feet. In fact, there is no inconsistency. The two techniques measure different aspects of global temperature, and both are influenced by a variety of factors, such as the presence of airborne materials from the eruption of the volcano, Mt. Pinatubo. When the satellite record is corrected for such factors, warming temperatures since the late 1970s are evident in both records, although rates are slightly different.

What does warming do? A warmer earth essentially speeds up the global water cycle. Because there is more evaporation at higher temperatures, soils will tend to dry out. Because there is more water in the atmosphere, there will also be more rain or snow in some areas. We may be seeing the first signs of changes in the water cycle - since the beginning of the century, precipitation in the U. S. has increased by about 6%, with about a 20% increase in the frequency of intense precipitation events, or heavy downpours. Such events have led to flooding, soil erosion, and even loss of life. (Figure 8) But in some midcontinental areas, increased evaporation has led to drought as the heavy rains fell elsewhere.

There is also evidence that regional ecosystems are responding to warming. Between 1981 and 1991, the length of the growing season in the northern high latitudes (between 45° and 70° N) increased by a total of up to 12 days, as documented by satellite imagery. "Greening" in spring and summer occurred up to eight days earlier, and vegetation continued to photosynthesize an estimated 4 days longer.

Sea level is also rising, mainly due to thermal expansion of the oceans and the melting and retreating of ice caps and glaciers. Over the last century, global mean sea level has risen 4 to 10 inches (10 -25 cm). During this century, mountain glaciers have retreated world-wide. Formerly frozen lands (permafrost) in the Alaskan arctic have begun to melt, damaging both ecosystems and infrastructure. Permafrost melting has produced sinkholes that have damaged roads, buildings, and airport runways. Melting and tundra warming will also lead to the release of trapped carbon and methane, creating an additional source of greenhouse gases. (Figure 9)

Climate Change Over the Next 100 years

Where are we headed? Even if it were possible to stabilize the rate at which CO₂ is added to the atmosphere, it would continue to accumulate and its concentration would continue to rise throughout the next century and beyond. If the world proceeds on a “business as usual” path, it is likely that we are headed for an atmospheric CO₂ concentration of more than 700 ppm by 2100, about double the current level. (Figure 10) State-of-the-art climate models suggest that this will result in a 2-6 °F increase in global temperatures over the next century. This is a rate of change not seen on the planet for at least the last 10,000 years. Furthermore, even if we stabilize atmospheric CO₂ at 700 ppm by the year 2100, it could take several more centuries before temperature also stabilized.

What are the projected extent and pattern of warming over the globe? The higher latitude (polar) regions will warm more than areas nearer to the equator. Some climate models project results for a “doubling” of CO₂ from preindustrial levels, or about 560 ppm. In a world with a stabilized CO₂ concentration of 560 ppm, the U. S. would eventually stabilize at a temperature 5 to 10° F warmer than at present. (Figure 11) These warmer temperatures would lead to soil drying in some regions, with moisture deficits estimated at 10 to 30% for the U. S. during the summer growing season. (Figure 12)

If emissions continue to rise to 4 times the pre-industrial level, or more than 1100 ppm, the estimated temperature increase for the U. S. would be 15 to 20° F, and soil moisture deficits could approach 30-50% during the growing season. (Figures 13 and 14)

Vulnerabilities and Potential Consequences

There is scientific uncertainty about exactly how, when, and where the Earth's climate will respond to increased concentrations of greenhouse gases in the future. Observations clearly show, however, that detectable changes are underway. Ecological systems have begun to respond to these changes, which are adding important new stresses on top of the effects of pollution, resource extraction, and non-sustainable management practices. Climatic changes from rapidly rising CO₂ concentrations would have widespread effects, some of them irreversible, on ecological systems, human health, and socioeconomic sectors. If we continue on our "business-as-usual" path for greenhouse gas emissions, CO₂ concentrations are likely to exceed 560 ppm and even 700 ppm, so that these effects could be much worse. There may also be surprises hidden in Earth's complex systems that may only surface as the future makeup of the atmosphere and the exact nature of climate responses unfold.

Worsening Health Effects - In general, developing countries are more vulnerable to climate change because of limited infrastructure and capital and greater dependence on natural resources. Children and the elderly are the most vulnerable population groups. Climate change will increase the risk of mortality from heat stress and from diseases that thrive in warmer climates, such as malaria, dengue and yellow fevers, encephalitis, and cholera.

- Mosquitos and other disease-carrying organisms are likely to expand their ranges northward, increasing the number of people exposed. The result could be, for example, 50-80 million additional malaria cases per year worldwide.
- Climate change can exacerbate air quality problems, such as smog, and increase levels of airborne pollen and spores that aggravate respiratory disease, asthma, and allergic disorders. (Figure 15) On the other hand, measures that reduce greenhouse gas emissions will have the added benefit of also reducing air pollution.

Rising Sea Level - Rising sea level erodes beaches and coastal wetlands, inundates low lying areas, and increases the vulnerability of coastal areas to flooding from storm surges and intense rainfall. Over the next century, sea level is expected to rise by estimates ranging from 6-37 inches (15-95 cm), with a "best guess" of 20 inches (50 cm). A 20 inch sea level rise will result in substantial loss of coastal land in the U.S., particularly along the southern Atlantic and Gulf coasts, which are currently subsiding and are particularly vulnerable. Sea level rise may eventually exceed 80 inches (2 m), and could be substantially more, depending on the extent to which the Greenland and Antarctic ice sheets melt.

- A 20 inch sea level rise would double the population at risk from storm surges, from roughly 45 million at present to over 90 million world-wide. A 40 inch (1

m) rise would triple the number.

- In Florida, one-third of the Everglades would be lost with only a 12 inch rise, and salt water intrusion would adversely affect delicate ecological communities and degrade the habitat for many species. (Figure 16)

Disruption of the Water Cycle - Among the most fundamental effects of climate change are intensification and disruption of the water cycle.

Droughts and floods - Intensification of the water cycle will produce more severe droughts in some places and floods in others. Such events are costly. Damages from the southern plains drought of 1996 were estimated at \$4 billion, the 1993 Mississippi River flood ranged from \$10 - \$20 billion, and the 1997 Red River flood in the northern plains cost an estimated \$ 2 billion.

Water quality and quantity - Areas of greatest vulnerability are those where quality and quantity of water are already problems, such as the arid and semi-arid regions of the U. S. and the world. (Figure 17)

- Climate change would likely increase stress in several US river basins, such as the Missouri, Arkansas, Texas Gulf, Rio Grande and Lower Colorado.
- Water scarcity in the Middle East and Africa is likely to be aggravated by climate change, increasing the risk of international conflict among countries such as Syria, Sudan, Egypt and Iraq, which depend on water supplies originating outside their borders

Shifting Forests - Climate change can dramatically alter the geographic distributions of vegetation types. The composition of one-third of the Earth's forests would undergo major changes as a result of climate changes associated with a CO₂ level of 700 ppm. Over the next 100 years, the ideal range for some North American forest species will shift by as much as 300 miles to the north, far faster than the forests can migrate naturally. Economically important species, such as sugar maple, may be lost from New England. (Figure 18).

Changing Natural Areas - Natural ecosystems, including those that make up our system of national parks and refuges - a \$ 3 billion annual investment - are highly vulnerable to degradation from climate change. The composition, geographic distribution, and productivity of many ecosystems will shift, leading to reductions in biological diversity and in the benefits they provide, such as clean water and recreation. Wetlands are particularly at risk. The wetlands of the prairie pothole region, which support half the waterfowl population of North America, could diminish in area and change dramatically in character in response to climate change. Mountain glaciers, which fluctuate rapidly in response to climatic change, will shrink. The glaciers of Glacier National Park have receded steadily for decades. By 1993, there had been a 73% reduction in the area of

eight prominent glaciers in the Park. (Figure 19)

Challenges to Agriculture and the Food Supply - Climate strongly affects crop yields. A CO₂ concentration of 700 ppm is likely to increase crop yields in some areas by as much as 30-40%, but decrease yields in other places by similar amounts, even for the same crop. A warmer, drier climate would reduce flexibility in crop distribution and increase irrigation demands. Expansions of the ranges of pests could also increase vulnerability and result in greater demand for, and use of, pesticides. Despite potentially large changes in yields, overall global food production is not expected to be altered substantially. Agricultural systems in the developed countries are highly adaptable and can probably cope with the expected range of climate changes without dramatic reductions in yields. It is the poorest countries, already subject to hunger, that are the most likely to suffer significant decreases in agricultural productivity. (Figure 20)

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Figure 17: Dry river bed (photo)

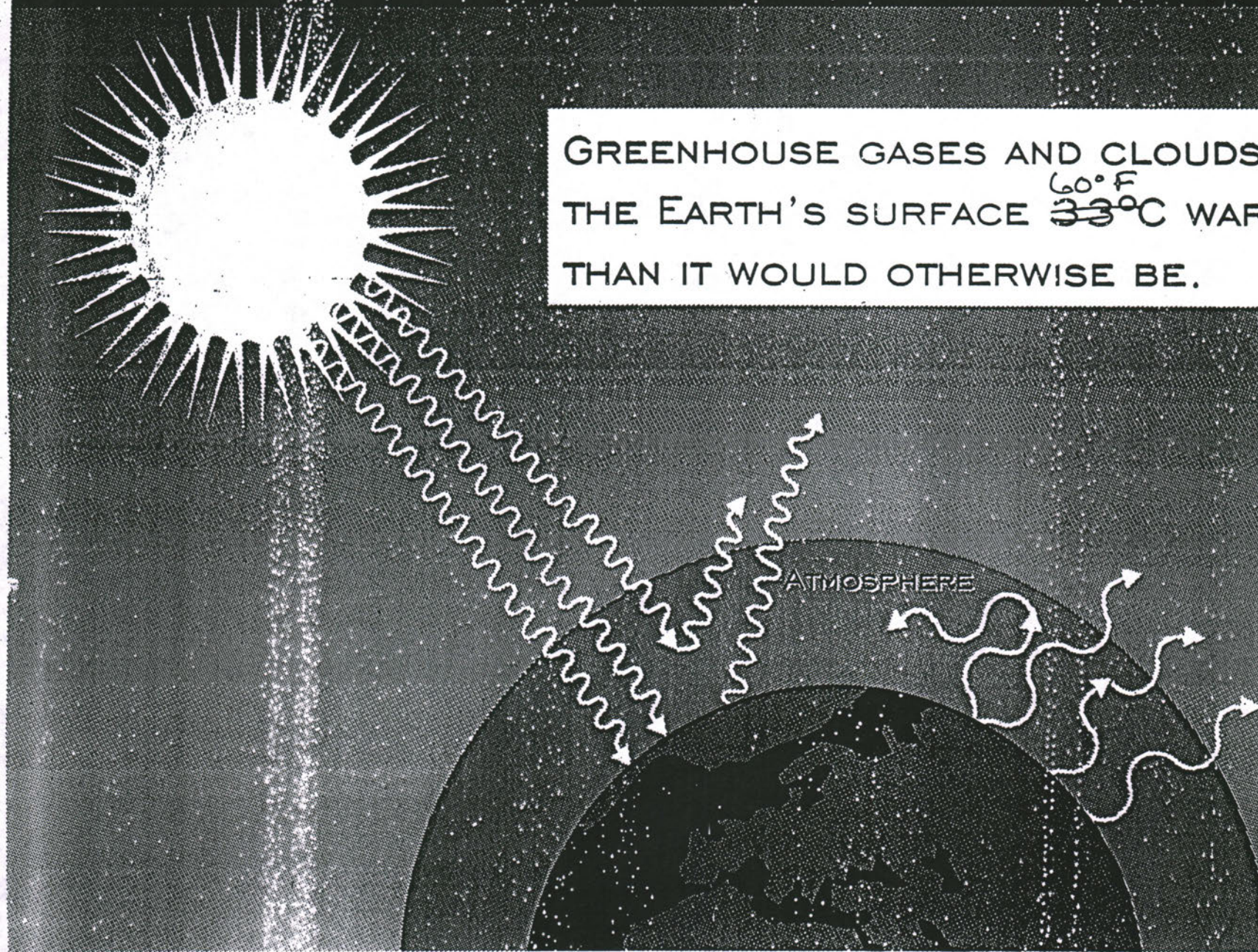
Figure 18: Sugar maples

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Figure 20: Agricultural resources under 2xCO₂

THE GREENHOUSE EFFECT

GREENHOUSE GASES AND CLOUDS KEEP
THE EARTH'S SURFACE ^{60°F}~~33°C~~ WARMER
THAN IT WOULD OTHERWISE BE.



Grabhorn
has

Figures 2 & 3

are

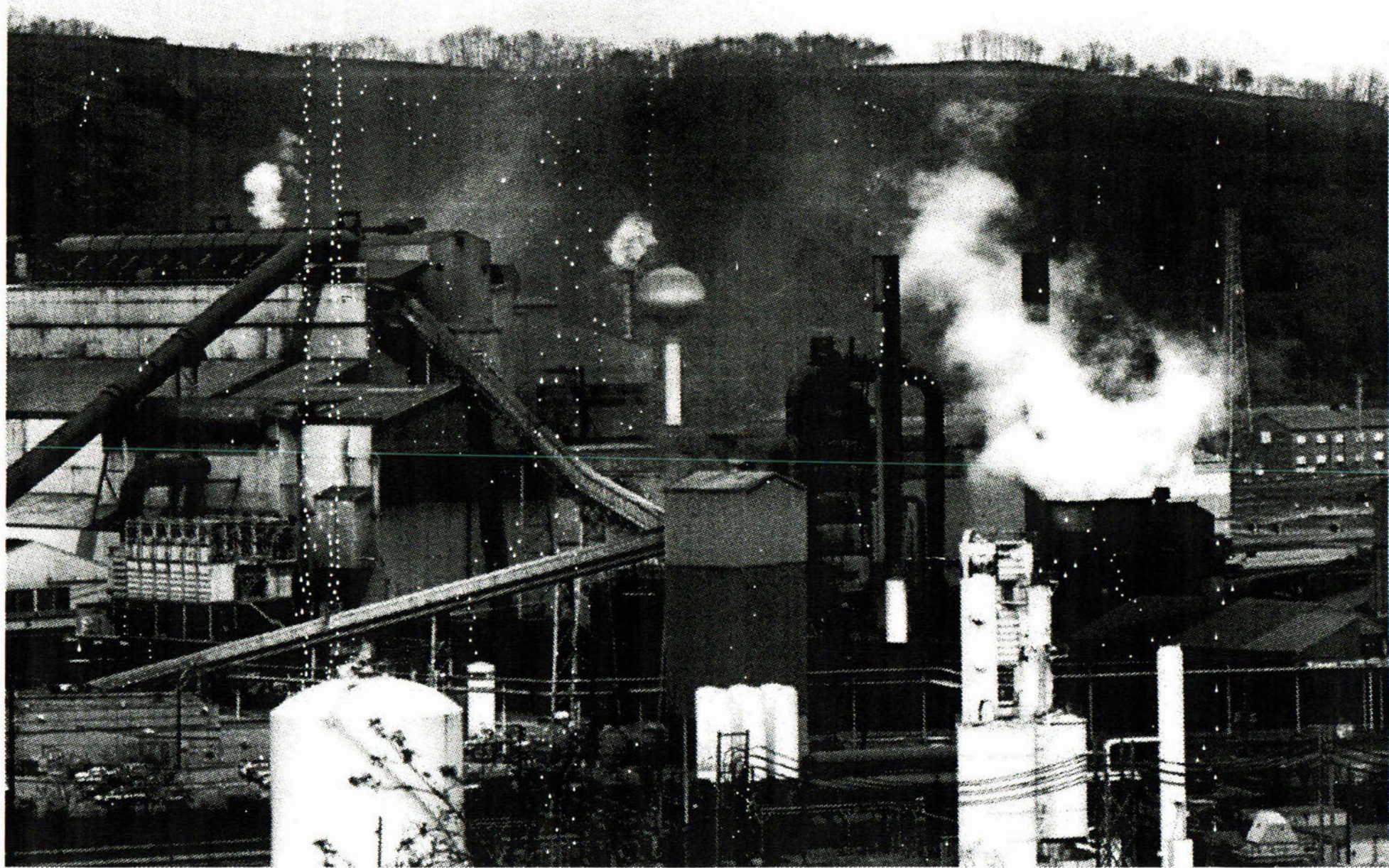
photographs of

Smoke stacks

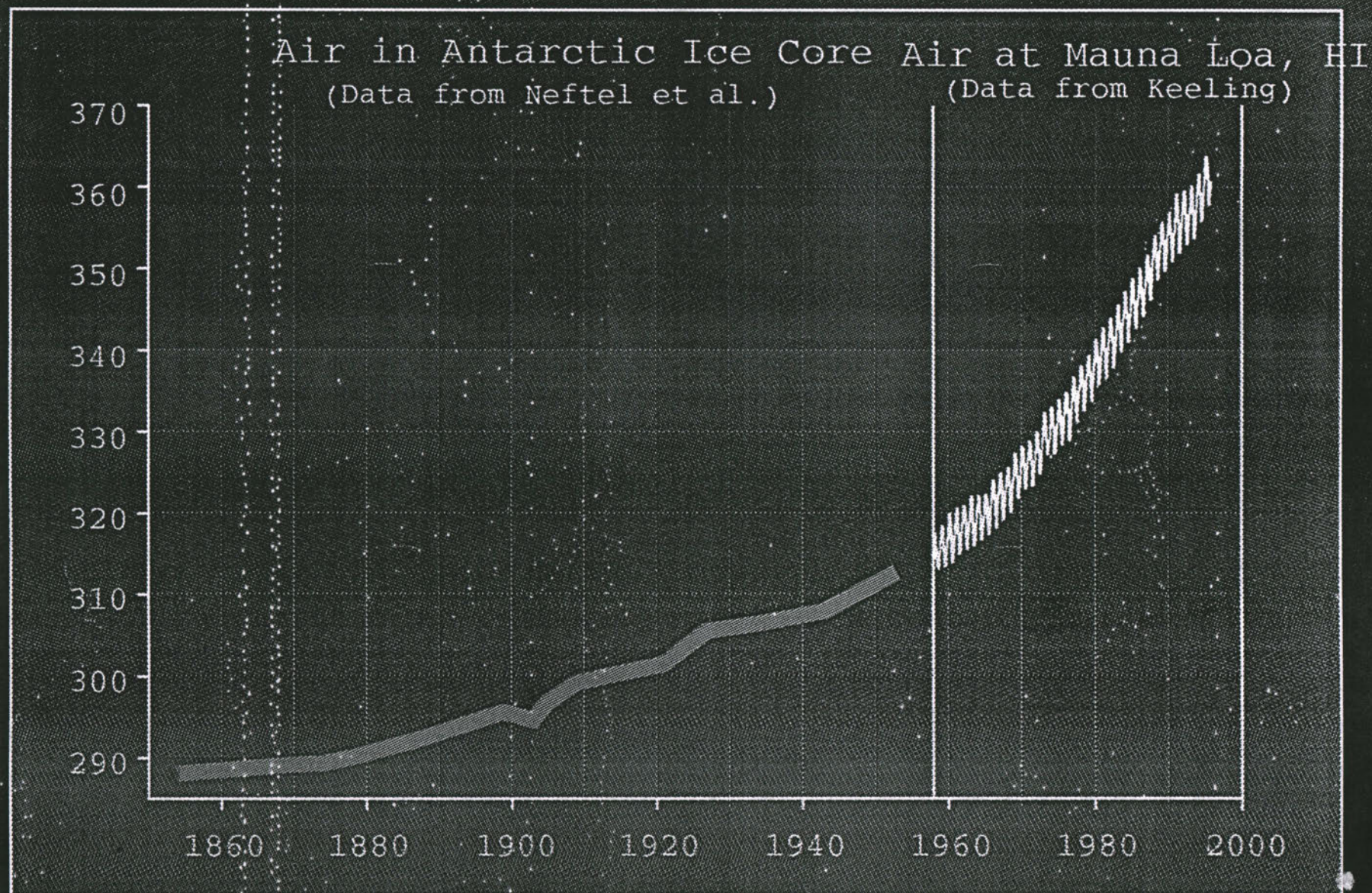
(Fig. 2)

&

Deforestation (Fig. 3)



Carbon Dioxide Concentrations



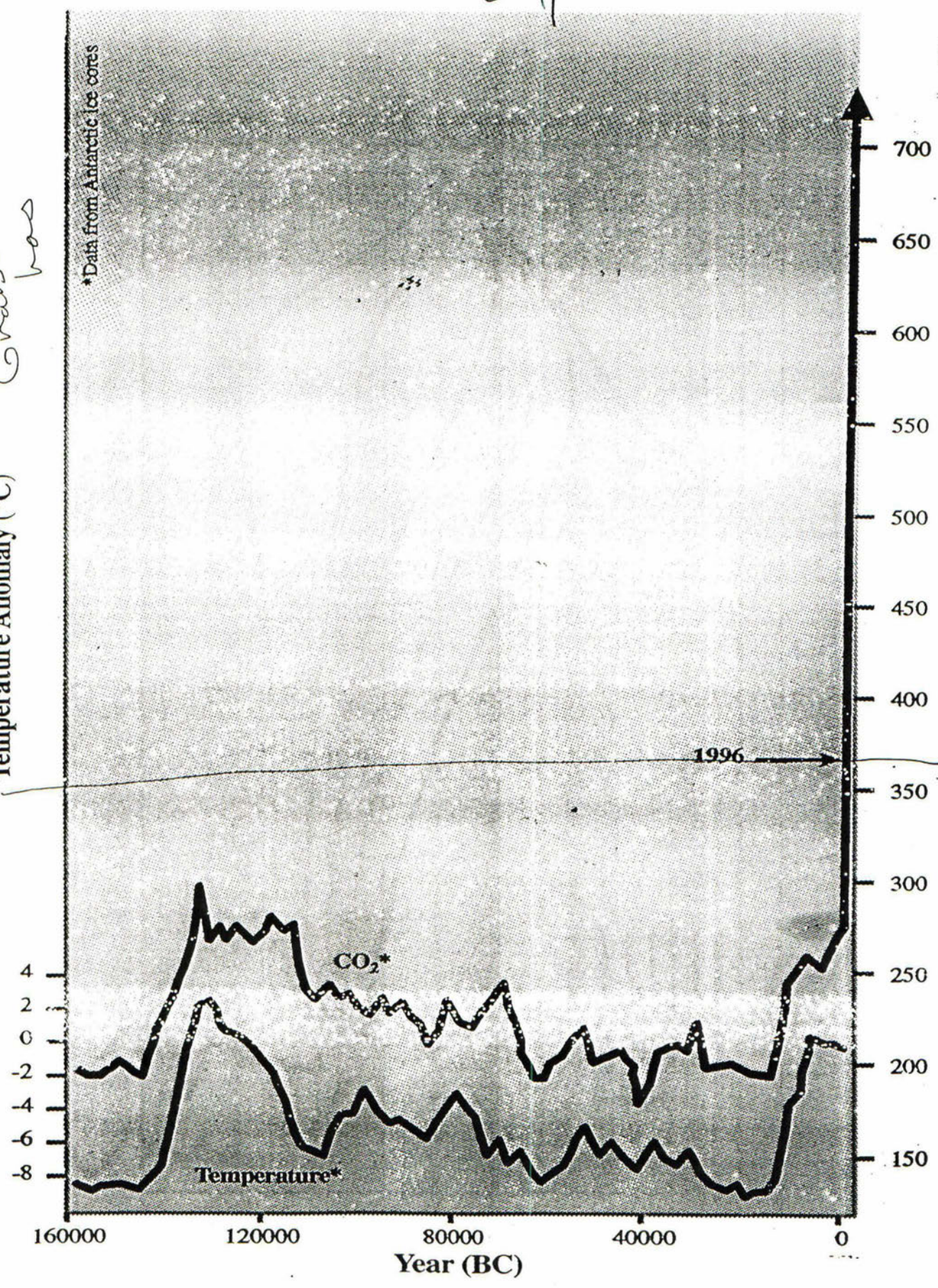
Up to present only

(5)

Graph has

Temperature Anomaly (°C)

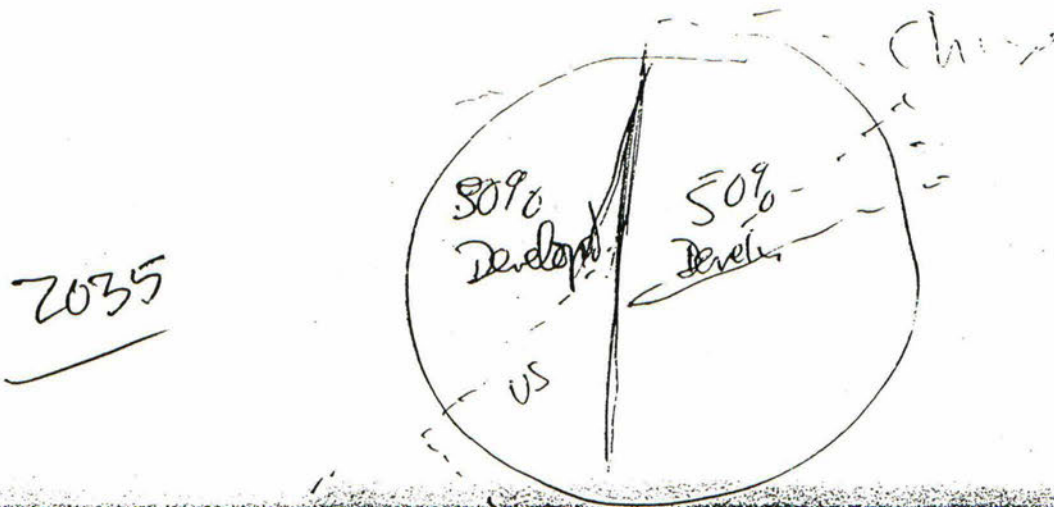
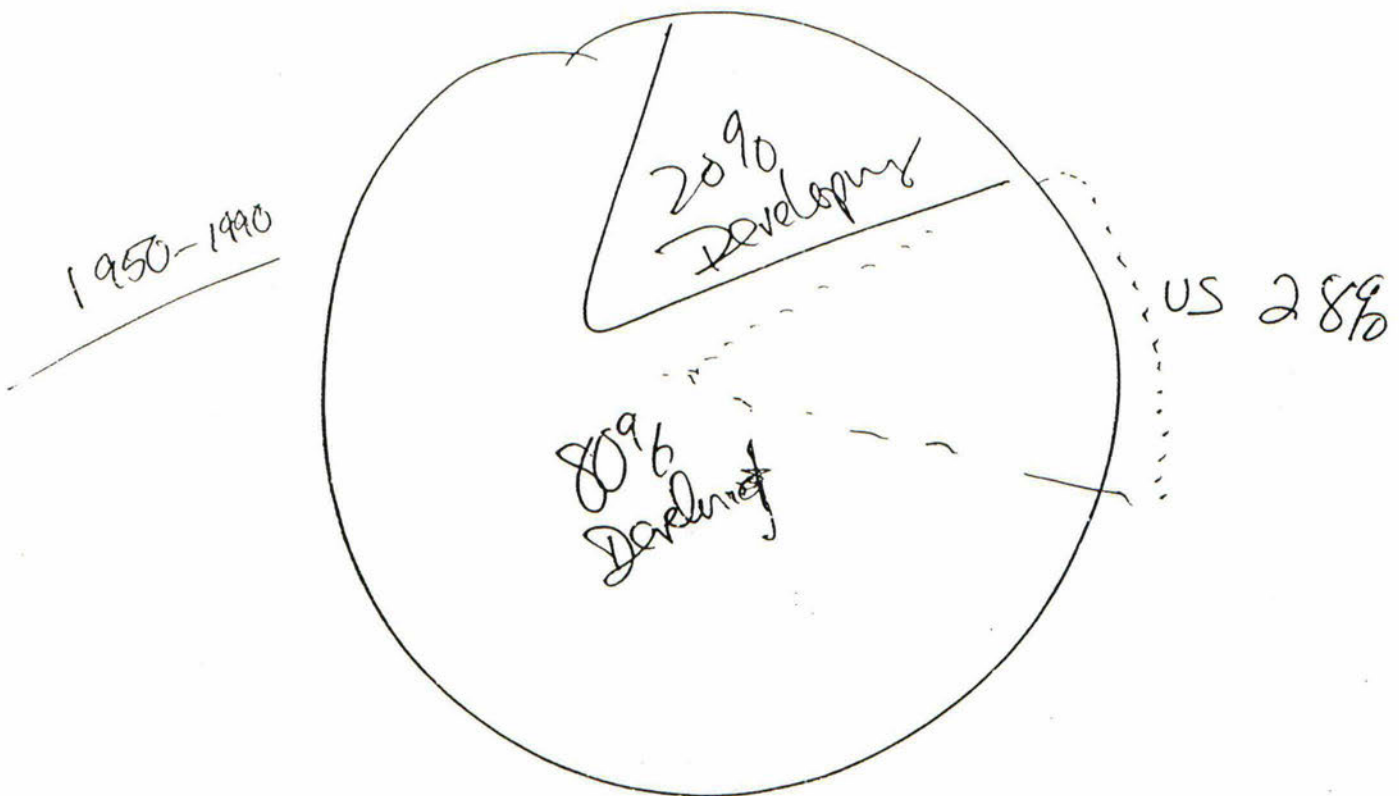
*Data from Antarctic ice cores



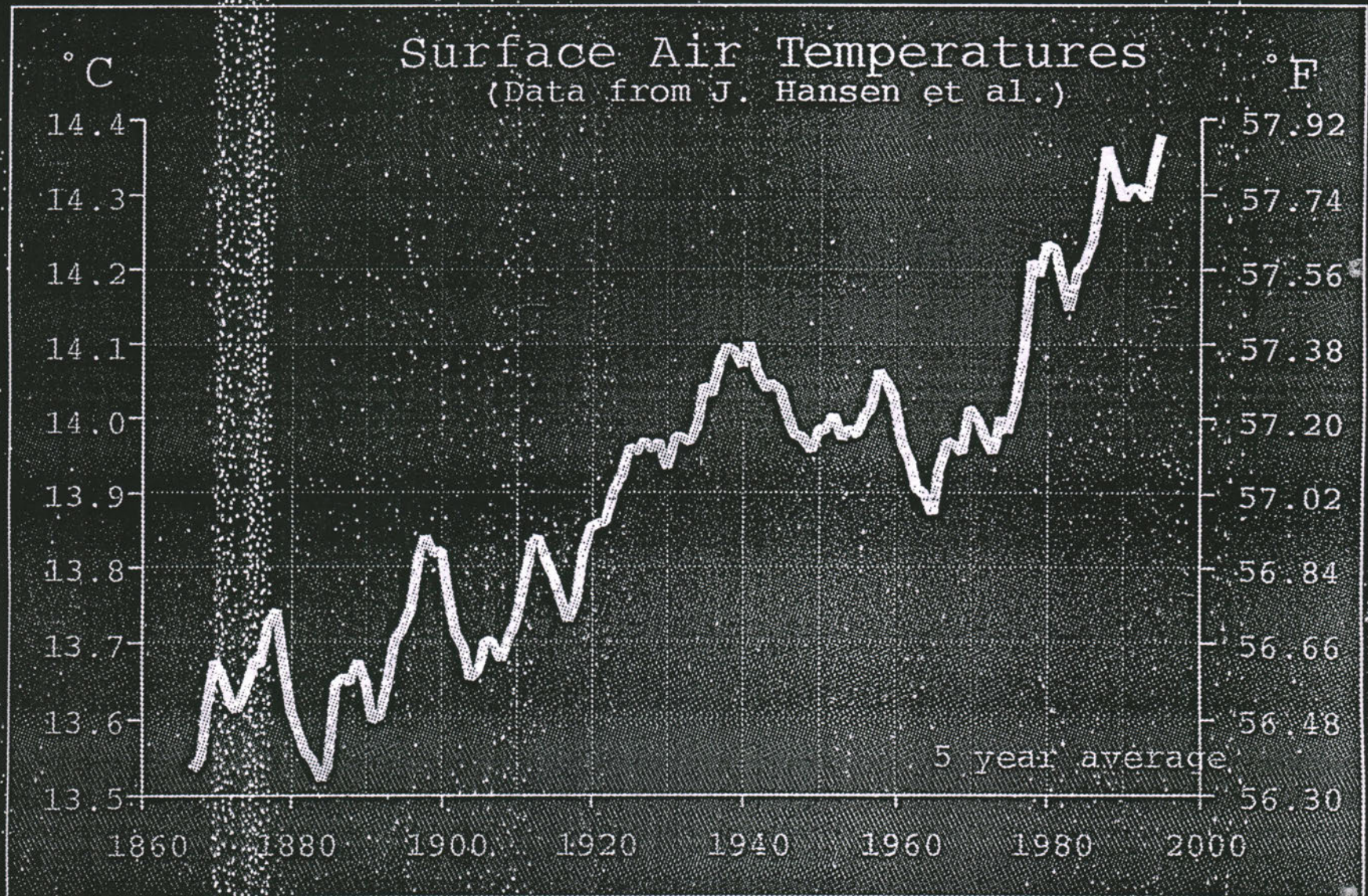
CO2 Concentration (ppmv)

Data. to
given to
global 8/21

6



Global Average Temperature



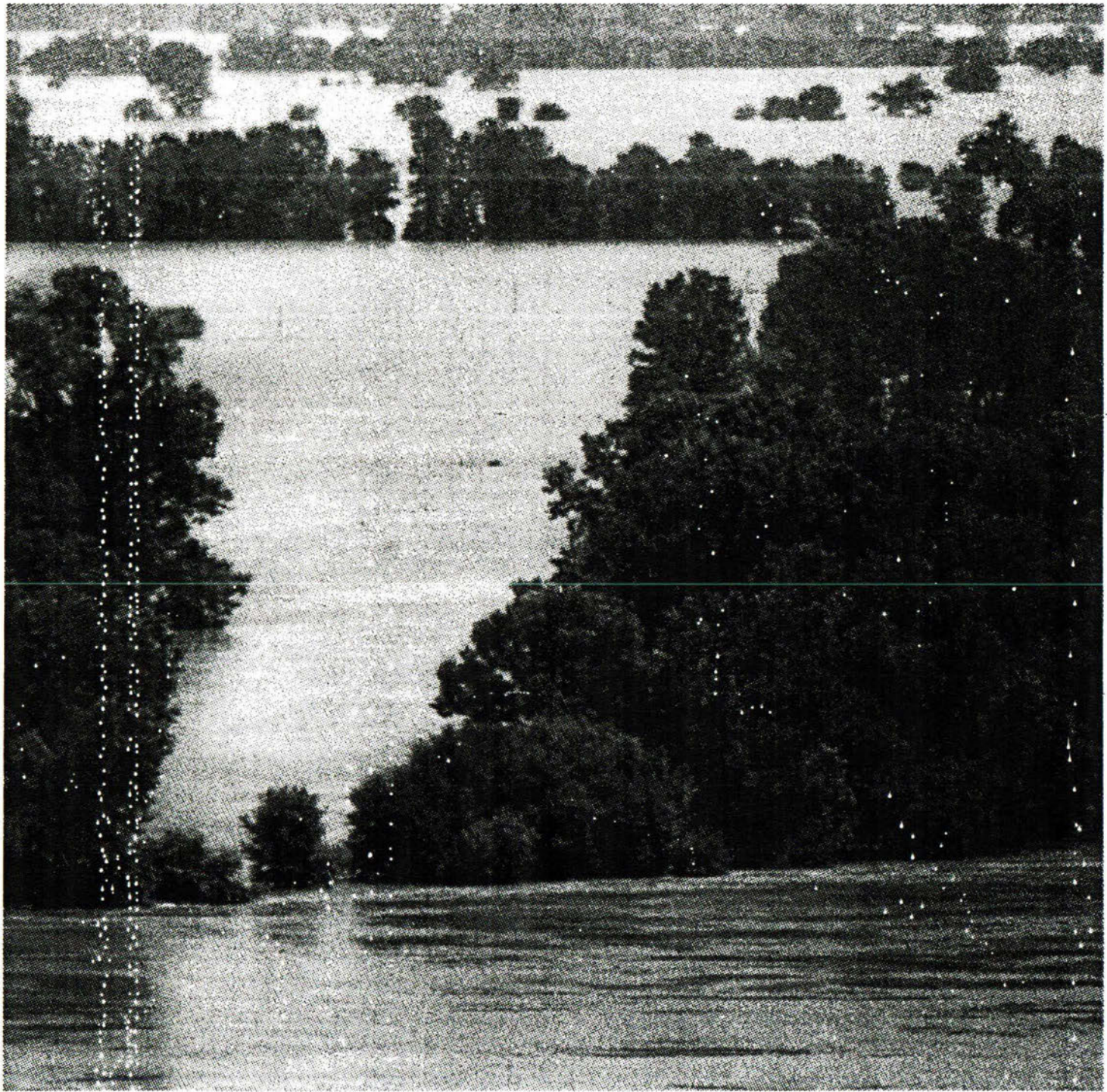
Corabhorn has

Figure 8

Grabber if
can get already
doesn't have

Photograph of image

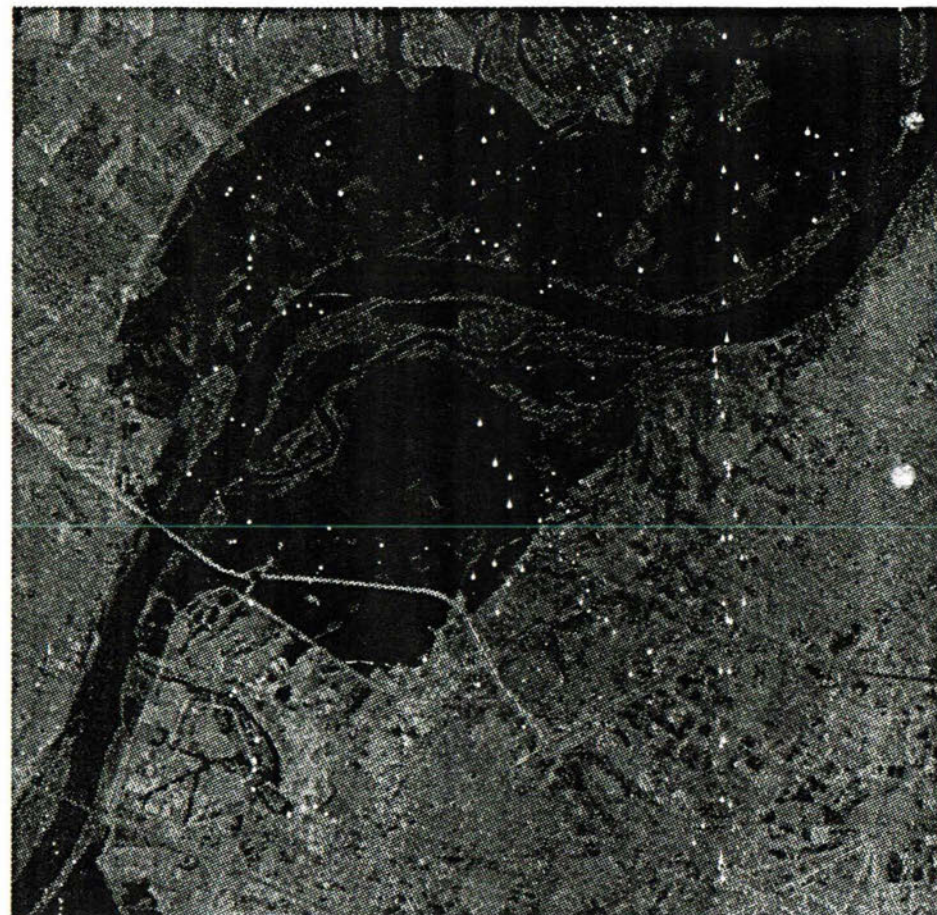
of
Hood



MISSOURI RIVER NEAR ST. LOUIS AIRPORT 1993



BEFORE



AFTER

Figure 9

Need!!

Photograph of

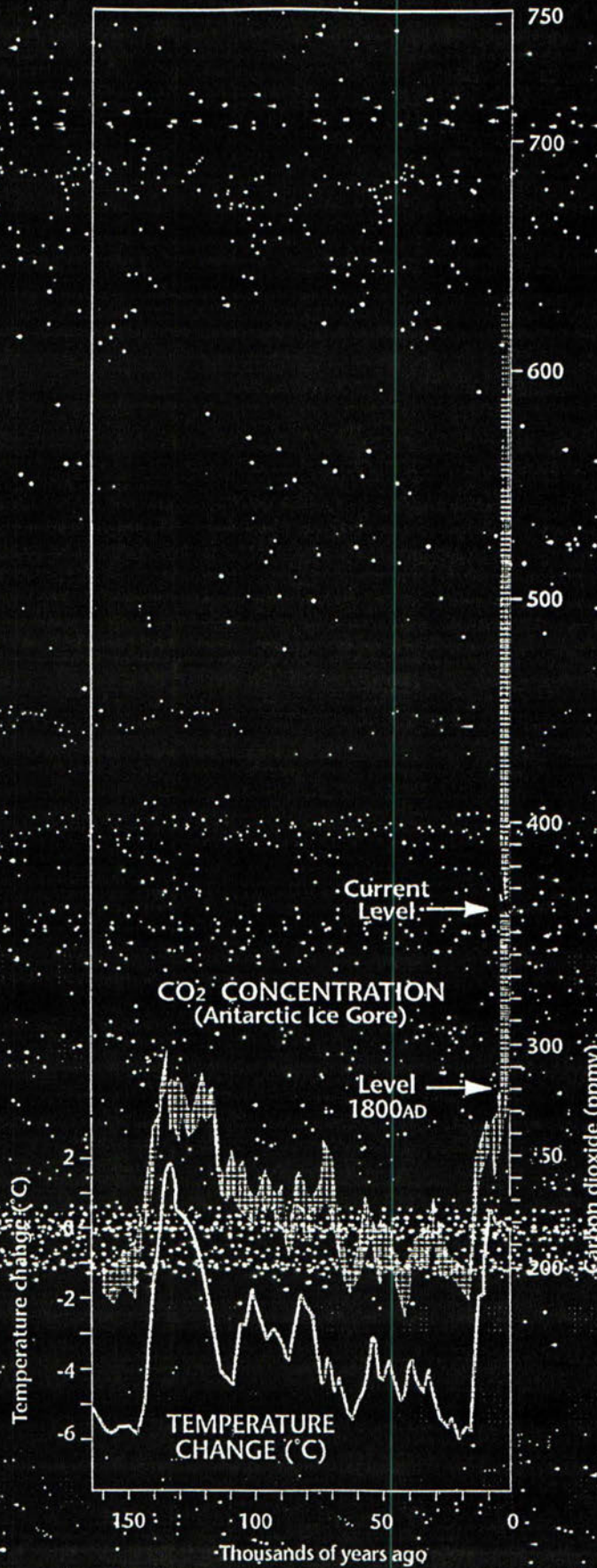
Permafrost melting

ie- Slumping road

or forest
slumping

(ie- Ask Gunter Keller)

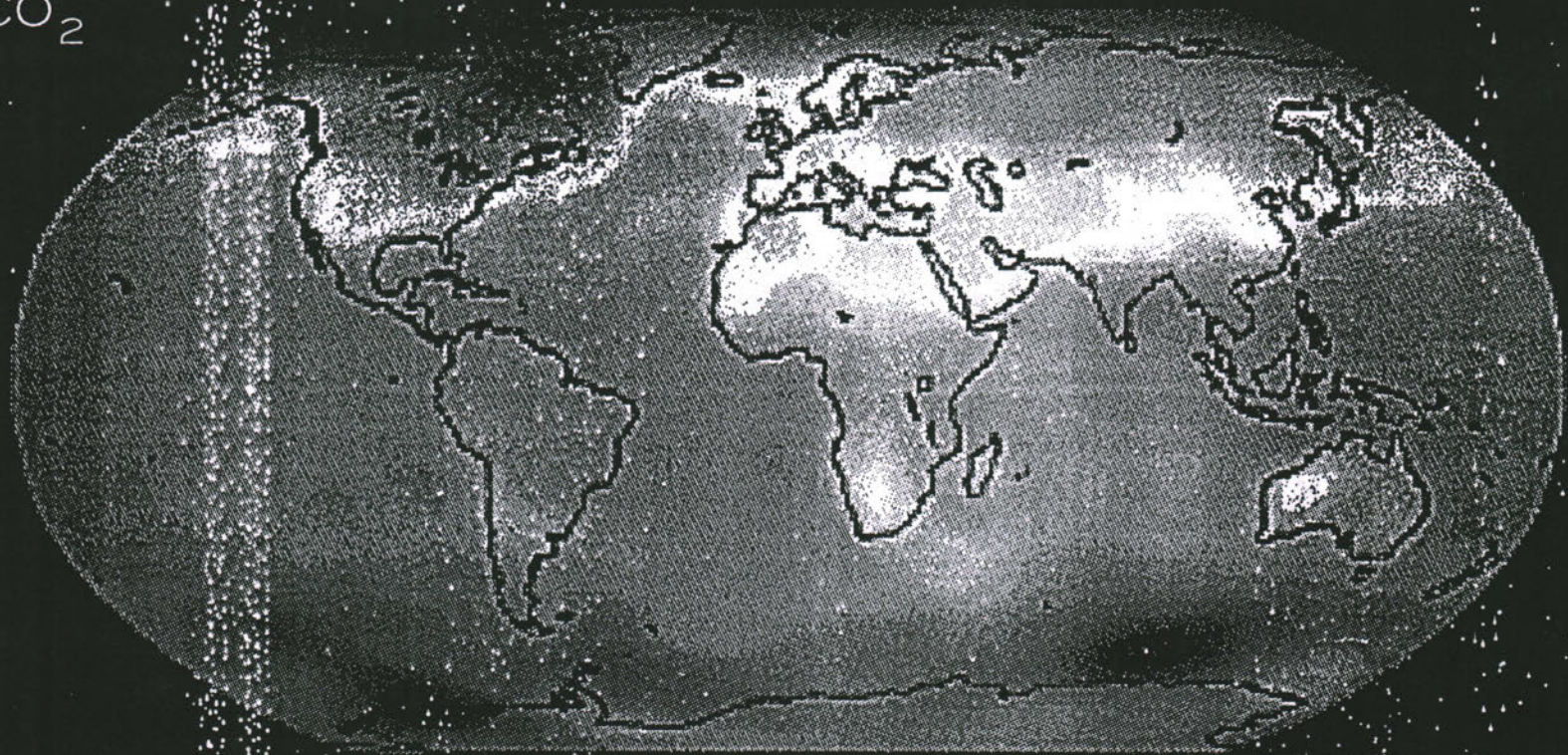
Atmospheric Carbon Dioxide Concentration and Temperature Change



Carbon Gas

SURFACE AIR WARMING (°F)

2xCO₂



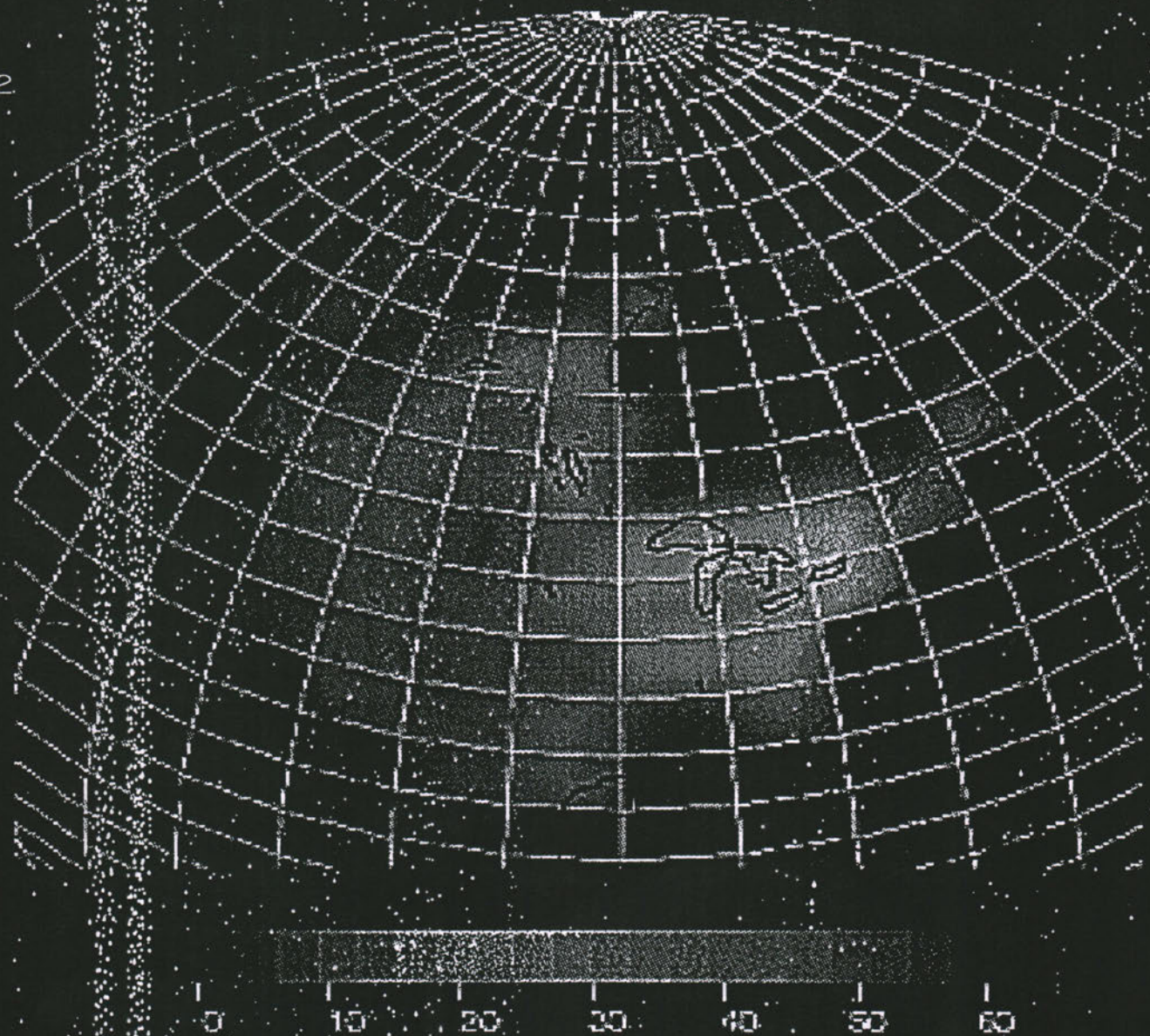
-5 0 5 10 15 20 25

SOURCE: GFDL R15 CLIMATE MODEL: CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

Get com get

PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

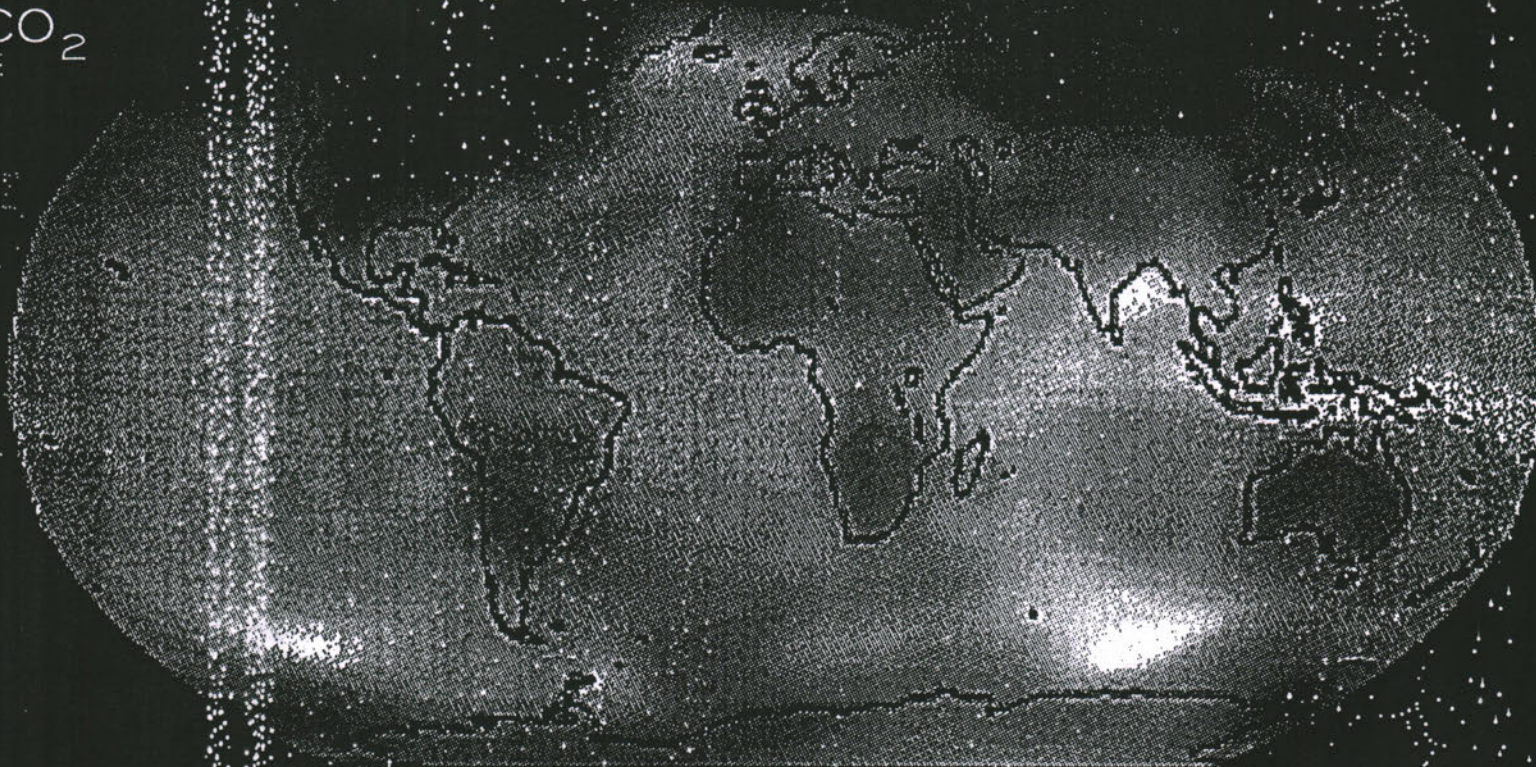
2xCO₂



9 cm get

SURFACE AIR WARMING (°F)

4xCO₂



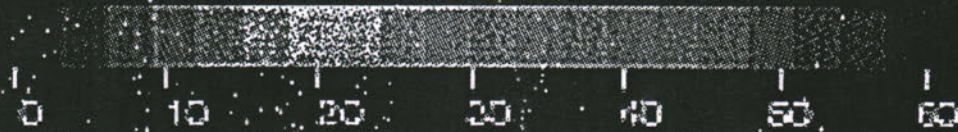
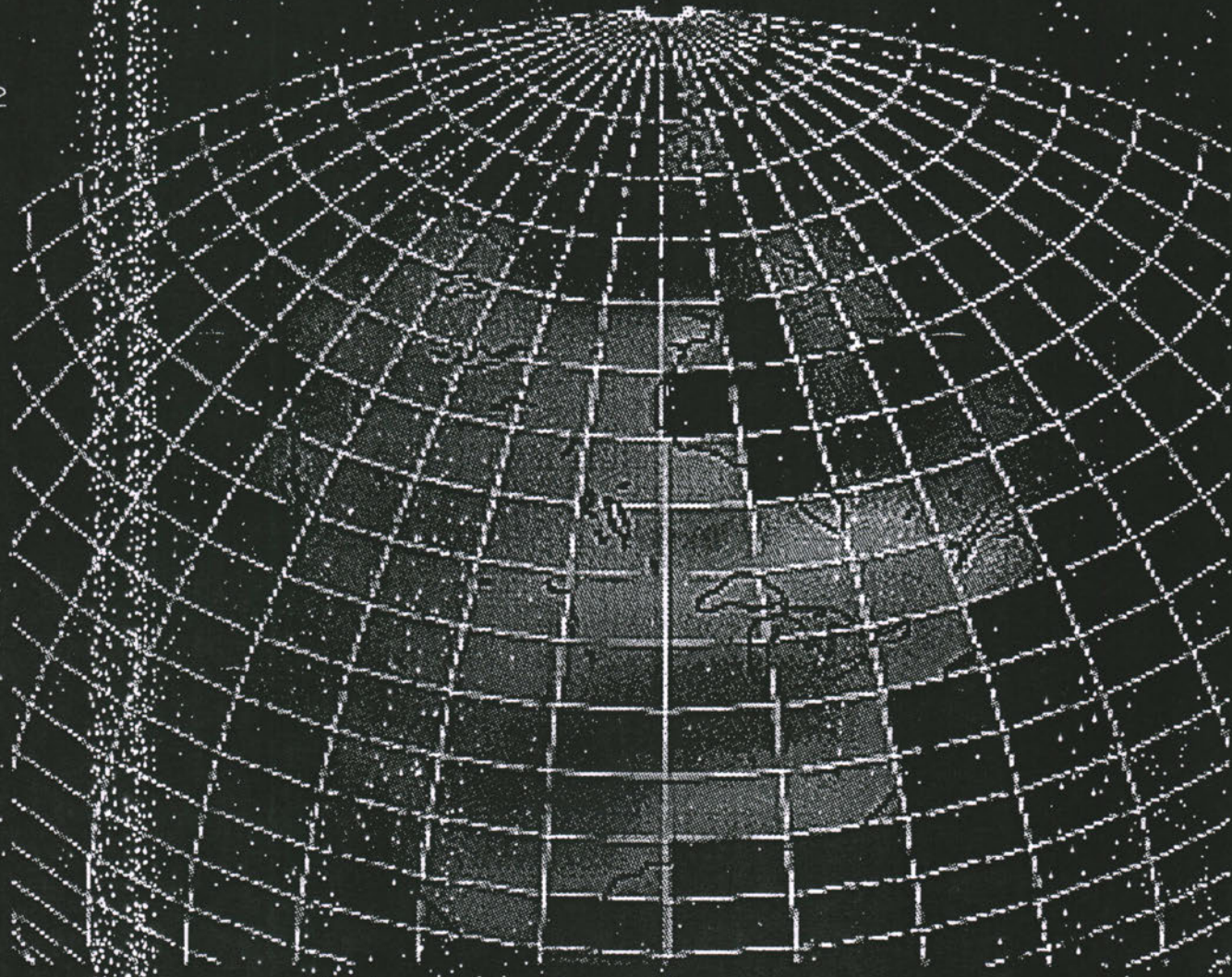
-5 0 5 10 15 20 25

SOURCE: GFDL R15 CLIMATE MODEL; CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

gribbau can get

PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

4xCO₂



9 cm get

Figure 15

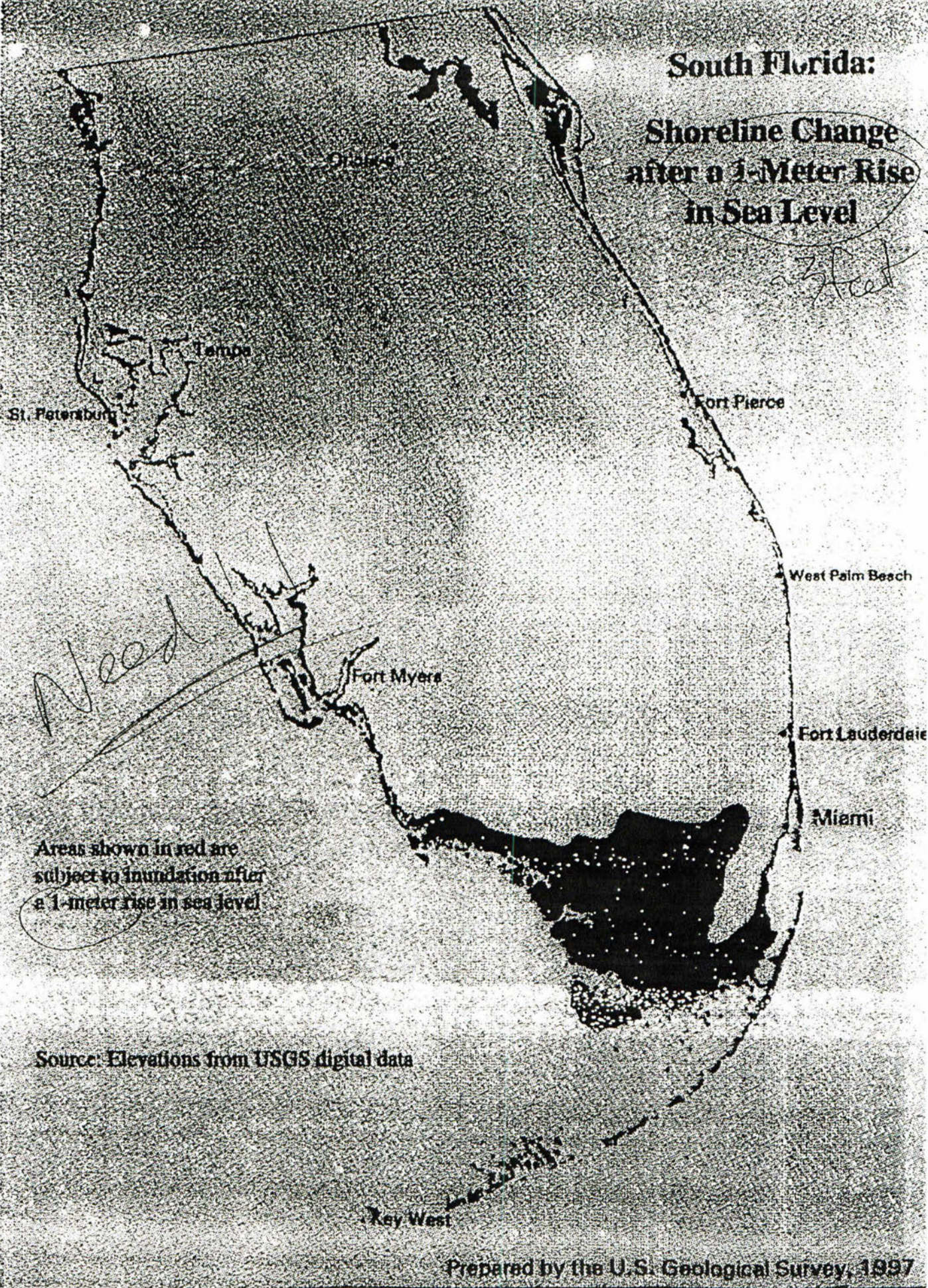
Photograph

of urban smog

problem
on set?

South Florida:

**Shoreline Change
after a 1-Meter Rise
in Sea Level**



Areas shown in red are
subject to inundation after
a 1-meter rise in sea level

Source: Elevations from USGS digital data

Prepared by the U.S. Geological Survey, 1997

Grab horn contact. Russell County, Georgia

Fig. 17

Photo of dry

River bed

grabber
can get?



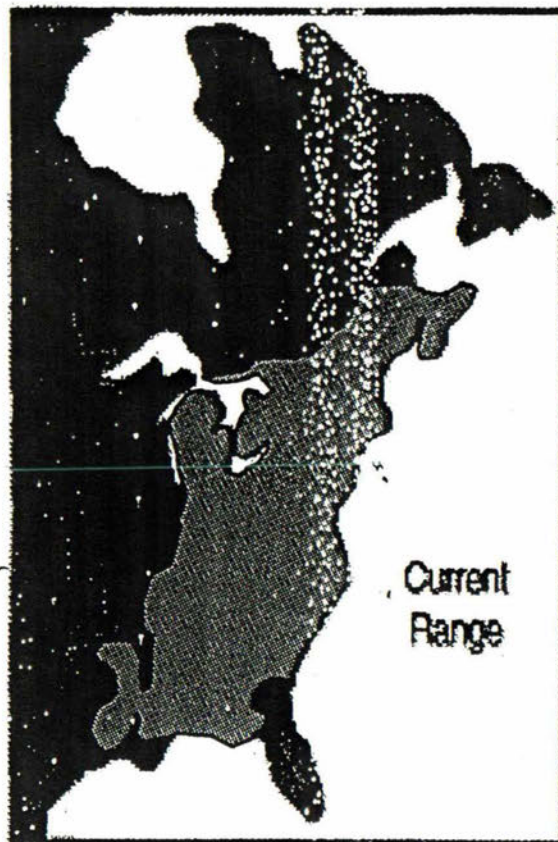
Cony (from Margaret Davis)

(Ummm) (all Margaret Davis)

Sugar maple

(18.)

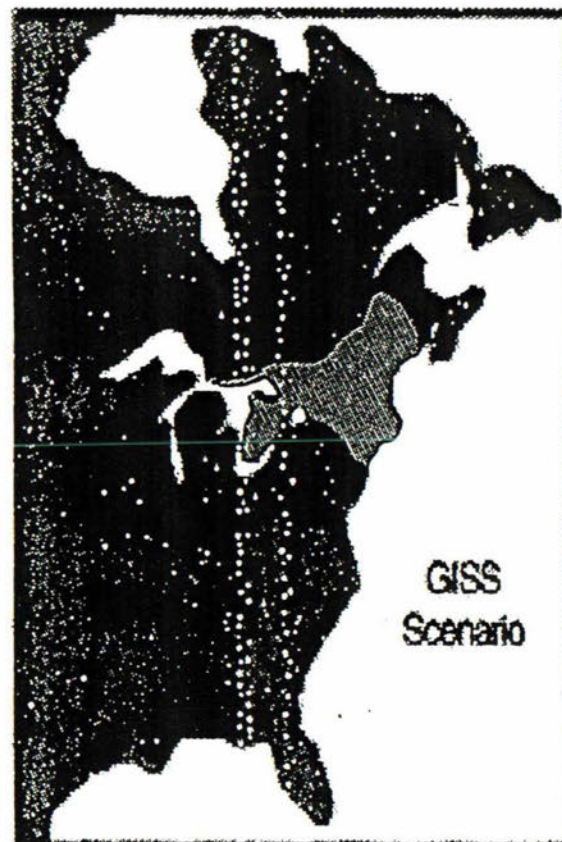
CURRENT AND PROJECTED RANGES OF BEECH TREES IN THE U.S. UNDER TWO MODEL SCENARIOS



Current
Range



GFDL
Scenario



GISS
Scenario



Current Growth



Projected New Growth

GLACIER SHRINKAGE IN GLACIER NATIONAL PARK

1850 - 1993



CURRENT AREA
OF GLACIERS

EXTENT OF GLACIERS
IN THE PAST

*Can San Gabbia
see for*

AGRICULTURAL RESOURCES: POTENTIAL CHANGE IN GRAIN YIELD DUE TO DOUBLED C_2



-30% -10% 10% 30%

PERCENT OF CHANGE IN YIELD

BASED ON GISS MODEL; PHYSIOLOGICAL CO_2 EFFECTS INCLUDED

SOURCE: ROSENZWEIG AND HILIEL (1993)

Need? ! Contract is in
Joel Sebring - EPA
offline 260-4029

Rising

Climate Change: State of the Knowledge Brochure

Covers:

Front: Earth picture (maybe one that shows how thin the atmosphere is)
Title

Inside: Text on climate change research programs: USGCRP, IPCC, IGBP, etc.

Back: Biosphere (the Living Earth)

Body:

Opening (abstract)

The Greenhouse Effect and Historical Emissions

Climate Change Over the Last 100 years

Climate Change Over the Next 100 years

Vulnerabilities and Potential Consequences

Opening ("Abstract")

1555
The Intergovernmental Panel on Climate Change recently stated that the balance of the scientific evidence now suggests that there is "a discernible human influence on global climate." The Earth's climate system is already experiencing rates of change faster than any during the last 10,000 years, the period in which modern civilization developed. The Panel estimated that an increase in global surface air temperature of about $3\frac{1}{2}^{\circ}\text{F}$ is likely by the year 2100, although the change could be as low as 2 and as high as $6\frac{1}{2}^{\circ}\text{F}$, depending on what the countries of the world do to control their emissions of carbon dioxide (CO_2) and other greenhouse gases in the intervening years.

The ultimate aim of the Framework Convention on Climate Change is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system." This level should be achieved soon enough to (1) allow ecosystems to adapt naturally to climate change, (2) ensure that food production is not threatened, and (3) enable sustainable economic development to proceed. While much work remains to be done to improve the precision of impact assessments, the risks of climate change are becoming increasingly apparent, and lend support for the idea that measures for mitigation and adaptation are warranted.

make it
clear
that

The Greenhouse Effect and Historical Emissions

Life as we know it is possible on Earth because of a natural greenhouse effect that keeps our planet about 60°F warmer than it otherwise would be. (Figure 1: Greenhouse effect) Water vapor, carbon dioxide (CO₂), and other trace gases, such as methane and nitrous oxide, trap heat and keep it from being lost by re-radiation back to space. With industrialization, the amounts of greenhouse gases added to the atmosphere by human activities have become significant. On a global scale, burning of coal, oil, and natural gas releases about 6 billion tons of carbon into the atmosphere each year. Land-use change, predominantly the clearing of forests for agriculture, contributes about 1-2 billion tons more per year globally. (Figures 2 and 3: Smokestacks; deforestation photos) The consequence is that there has been a steady increase in greenhouse gas concentrations in the atmosphere.

Since 1860, CO₂, the most important human-derived greenhouse gas, has increased 30%, from 280 to 360 parts per million (Figure 4: CO₂ record, 1860 to present). Methane concentration has also more than doubled, and nitrous oxide has risen by 15%. Over a much longer time scale, there is a clear relationship between CO₂ levels and the global temperature record. Fluctuations of CO₂ and temperature have closely mirrored each other over the last 160,000 years. (Figure 5: CO₂ and temperature record over last 160,000 years as measured in ice cores)

Whose emissions are in the atmosphere? From 1950 to 1990, 80% of total CO₂ emissions came from the developed countries, with the United States the largest single source. (Figure 6: 1950-1990 vs 2035 pie charts). More recently, the developing countries' share of emissions from the burning of fossil fuels has grown from a mere 20% to about 35%. Over the next few decades, 90% of the world's population growth will take place in the developing countries, which will account for 50% of total global emissions by 2035 if current trends continue. China, which has already become the second largest source, will displace the U. S. as the largest emitter. Per capita energy use in the developing countries, which is currently only 1/10 to 1/20 of our level, will also increase.

(By —)

make clear that this is only a small
amount of total CO₂ - ~~but~~
so that human industrial CO₂ isn't
large % - yet it tips balance on a
delicately balanced atmospheric system
& that is the pt of the danger...

Climate Change Over the Last 100 years

to a level

What has happened to date? The Intergovernmental Panel on Climate Change's Second Assessment Report in 1995 described a series of changes that have already been observed. Over the last century, the average surface temperature of the Earth has increased by about 0.5 - 1.0 °F, which is as high or higher than it has been in any century since at least 1400 AD. The eleven warmest years this century have all occurred since 1980, with 1995 the warmest on record. (Figure 7: Global average temperature) Critics have pointed to an apparent discrepancy between the long term surface temperature measurements and the short term satellite observations of the atmosphere, maintaining that the satellite observations actually show that the Earth is cooling. The two techniques measure different aspects of global temperature, and both are influenced by a variety of factors, such as the presence of local pollution. When the satellite record is corrected for an unusual warming at its start (due to an El Niño) and an unusual cooling at its end (due to the eruption of the volcano, Mt. Pinatubo), warming temperatures since the late 1970s are evident in both, although rates are slightly different.

In fact there is no inconsistency.

What does warming do? A warmer earth essentially speeds up the global water cycle. Because there is more evaporation at higher temperatures, there is more water in the atmosphere that will come down as rain or snow. We may be seeing the first signs of a change in the water cycle - since the beginning of the century, precipitation in the U. S. has increased by about 6%, with about a 20% increase in the frequency of intense precipitation events, or heavy downpours. Such events lead to flooding, soil erosion, and even loss of life. (Figure 8: Flood picture) But in some midcontinental areas, warming increases evaporation and leads to drought.

There is also evidence that regional ecosystems are responding to warming. Between 1981 and 1991, the length of the growing season in the northern high latitudes (between 45° and 70° N) increased by a total of up to 12 days. "Greening" in spring and summer occurred up to eight days earlier, and vegetation continued to photosynthesize an estimated 4 days longer. There also appeared to have been approximately a 10% increase in carbon uptake by plants, possibly due to the longer growing season and a CO₂ fertilization effect.

Sea level is also rising, due primarily to thermal expansion of the oceans and the melting and retreating of ice in glaciers and ice caps. Over the last century, global mean sea level has risen 4 to 10 inches (10 -25 cm). [Add text on permafrost.] (Figure 9: Permafrost melting photo) During this century, mountain glaciers have ~~already~~ retreated world-wide.

Climate Change Over the Next 100 years

(is that for 700 or just a "blum"?)

Where are we headed? Even if it were possible to stabilize the rate at which CO_2 is flowing into the atmosphere, it would continue to accumulate and its concentration continue to rise throughout the next century and beyond. If the world proceeds on a "business as usual" path, it is likely that we are headed for an atmospheric CO_2 concentration of more than 700 ppm by 2100, about double the current level. (Figure 10: VP chart with future added on) Predictions from General Circulation Models (GCMs) are for an ensuing 2-6° F rise in global temperature over the next century - a rate of change not seen on the planet at least the last 10,000 years.

What are the projected extent and pattern of warming over the globe? In a world with a CO_2 concentration of 560 ppm, a 5 to 10° F change for the U. S. will not be evenly distributed, but will be amplified at the higher latitudes. (Figure 11: 2x CO_2 surface air warming) These warmer temperatures would lead to soil drying in some regions, with moisture deficits estimated at 10 to 30% for the U. S. (Figure 12: 2x CO_2 reduction in soil moisture)

3 or

But there is no indication that rising CO_2 levels will stop at 700 ppm. Rather, it is quite possible that they will continue to rise to 4 times the pre-industrial level, or more than 1100 ppm, given current emission rates. For a quadrupling of CO_2 , the estimated temperature increase for the U. S. would be 15 to 20° F, and soil moisture deficits could approach 30-50%. (Figures 13 and 14: 4x CO_2 surface air warming and soil moisture reduction)

[2 4 by 4
2-6° F]

[When?
cauf-1
here]

Vulnerabilities and Potential Consequences

Although there is scientific uncertainty about exactly how, when, and where the Earth's climate will respond to increased concentrations of greenhouse gases in the future, observations clearly show that detectable changes are underway and that ecological systems are responding to these changes. These changes are adding important new stresses on ecological and socioeconomic systems that are already affected by pollution, increasing resource extraction, and non-sustainable management practices. Climatic changes that would result from a doubling of CO₂ would have pervasive effects, some of them irreversible, on ecological systems, human health, and socioeconomic sectors:

Health Effects - In general, developing countries are more vulnerable to climate change because of limited infrastructure and capital and greater dependence on natural resources. Children and the elderly are the most vulnerable population groups. Climate change will increase the risk of mortality from heat stress and from diseases that thrive in warmer climates, such as malaria, dengue and yellow fevers, encephalitis, and cholera.

- Mosquitos and other disease-carrying organisms are likely to expand their ranges northward, increasing the number of people exposed. The result could be, for example, 50-80 million additional malaria cases per year worldwide.
- Climate change can exacerbate air quality problems, such as smog, and increase levels of airborne pollen and spores that aggravate respiratory disease, asthma, and allergic disorders. (Figure 15: Smog photo)

Sea Level Rise - Sea level is expected to rise by 20 inches (50 cm) over the next century and by at least 80 inches (2 m) before equilibrium is reached several centuries in the future. Rising sea level erodes beaches and coastal wetlands, inundates low lying areas, and increases the vulnerability of coastal areas to flooding from storm surges and intense rainfall. A 20 inch sea level rise would double the population at risk from storm surges, from roughly 45 million at present to over 90 million world-wide. A 40 inch (1 m) rise would triple the number. In Florida, one-third of the Everglades would be lost with a 40 inch rise, and salt water intrusion would adversely affect delicate ecological communities and degrade the habitat for many species. (Figure 16: Florida shoreline with sea level rise) Even the 20 inch rise projected for the next century will result in substantial loss of coastal land in the U.S., where the Atlantic and Gulf Coasts are particularly vulnerable. Sea level rise in a "4 times" CO₂ world would be likely to exceed 80 inches (2 m), and could be substantially more depending on the extent to which the Greenland and Antarctic ice sheets melt.

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(compared to pre-industrial) for DEFINING Earlier

But PAN would go way beyond doubling - or that the effects sketched out in attached charts (based on research) & simulations of doubling - likely to be considerably worse

At some time measures to control some of the consequences have the beneficial side effect of reducing etc.

likely from what levels of CO₂?

1993 Mississippi River flood. Areas of greatest vulnerability are those where quality and quantity of water are already problems, such as the arid and semi-arid regions of the U. S. and the world. (Figures 17: dry river bed picture)

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repeated
needed

Fig 1 Greenhouse effect

Fig. 2 Smokestack Photo

Fig. 3 Deforestation — Photo

Fig. 4 CO₂ concentrations 1860-present

Fig. 5 VP chart of CO₂ + temp over 160,000 y
↳ only up to present

New
Fig. 6 1950-1990 vs. 2035
pie charts

Fig. 7 Global Ave temperature 1860-present

Fig. 8 Photo of Floods

Fig. 9 Photo of permafrost melting

Fig. 10 VP chart including projections
of CO₂ + temp.

Fig. 11 Surface warming 2x CO₂

Fig. 12 90 Soil moisture reduction 2x CO₂

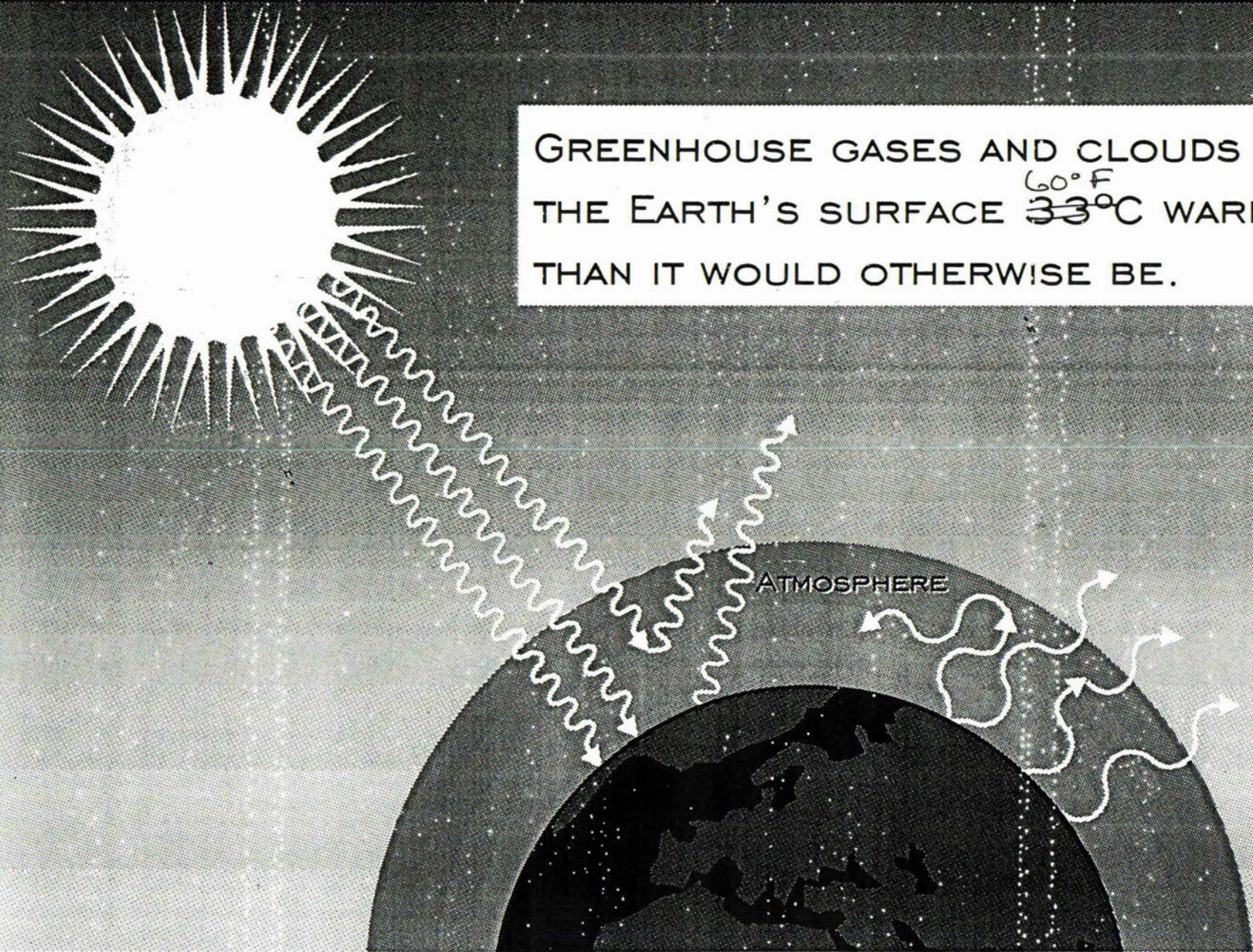
Fig. 13 Same as Fig. 11 4x CO₂

Fig. 14 " " Fig. 12 "

- Fig. 15 Photo of urban smog
- Fig. 16 South Florida shoreline
w/ sea level rise
- Fig. 17 Photo of dry river bed
- Fig. 18 Maps of Sugar Maple
under diff scenarios
- Fig. 19 Glacier Natl Park
- Fig. 20 Ag resources under doubled
CO₂

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GREENHOUSE GASES AND CLOUDS KEEP
THE EARTH'S SURFACE ^{60°F}~~33°C~~ WARMER
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Figures 2 & 3

are

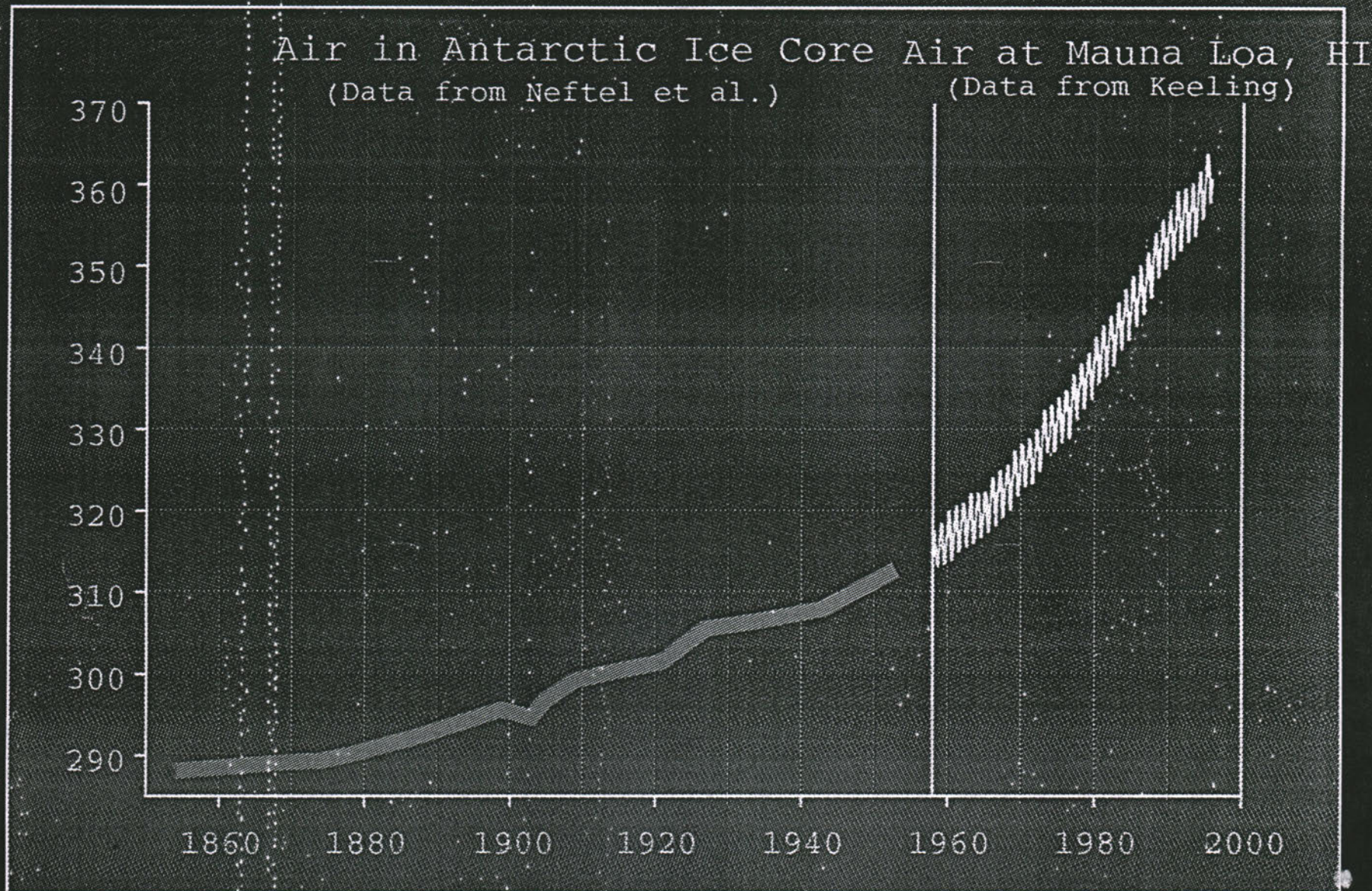
photographs of

Smoke stacks (Fig. 2)

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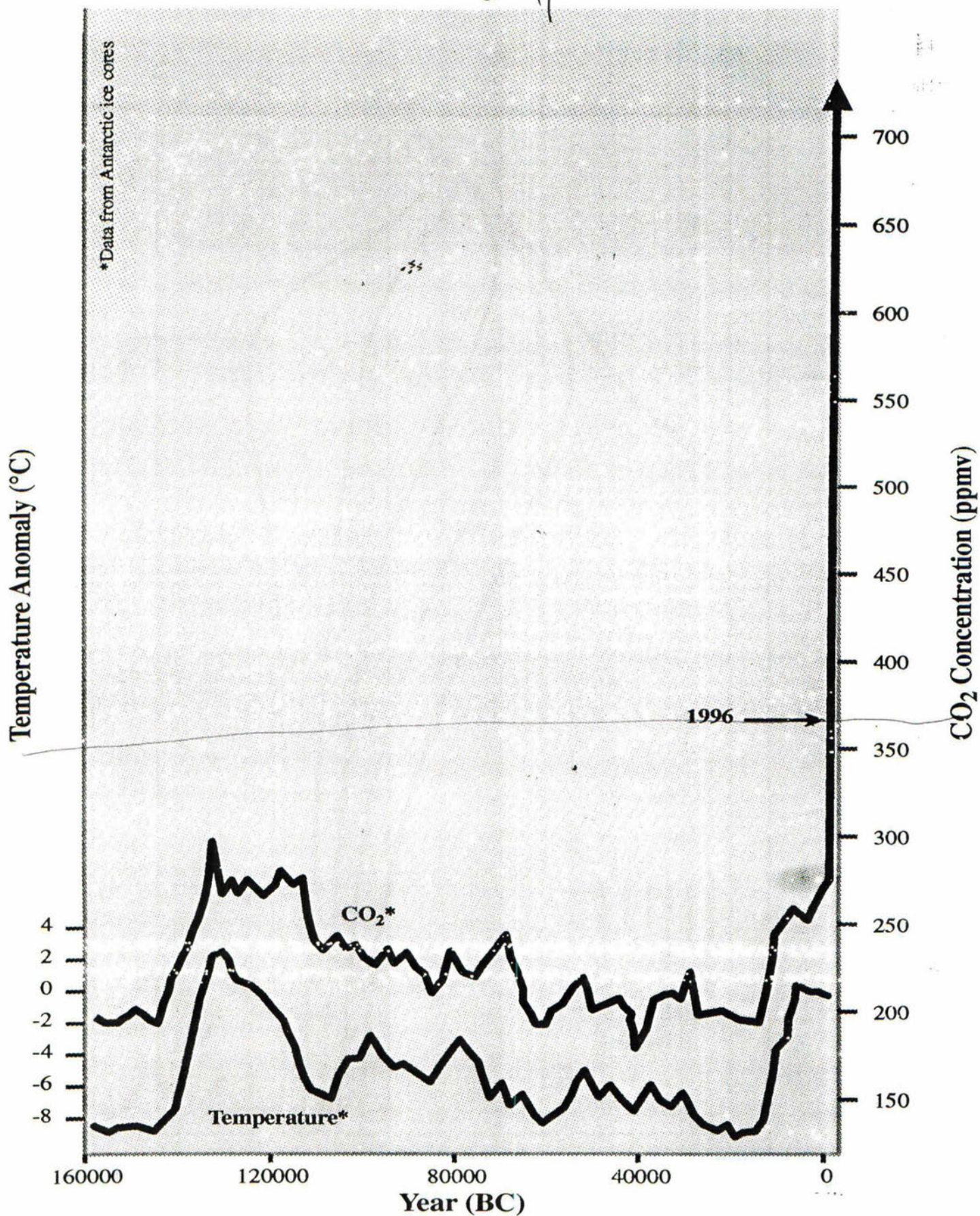
Deforestation (Fig. 3)

Carbon Dioxide Concentrations



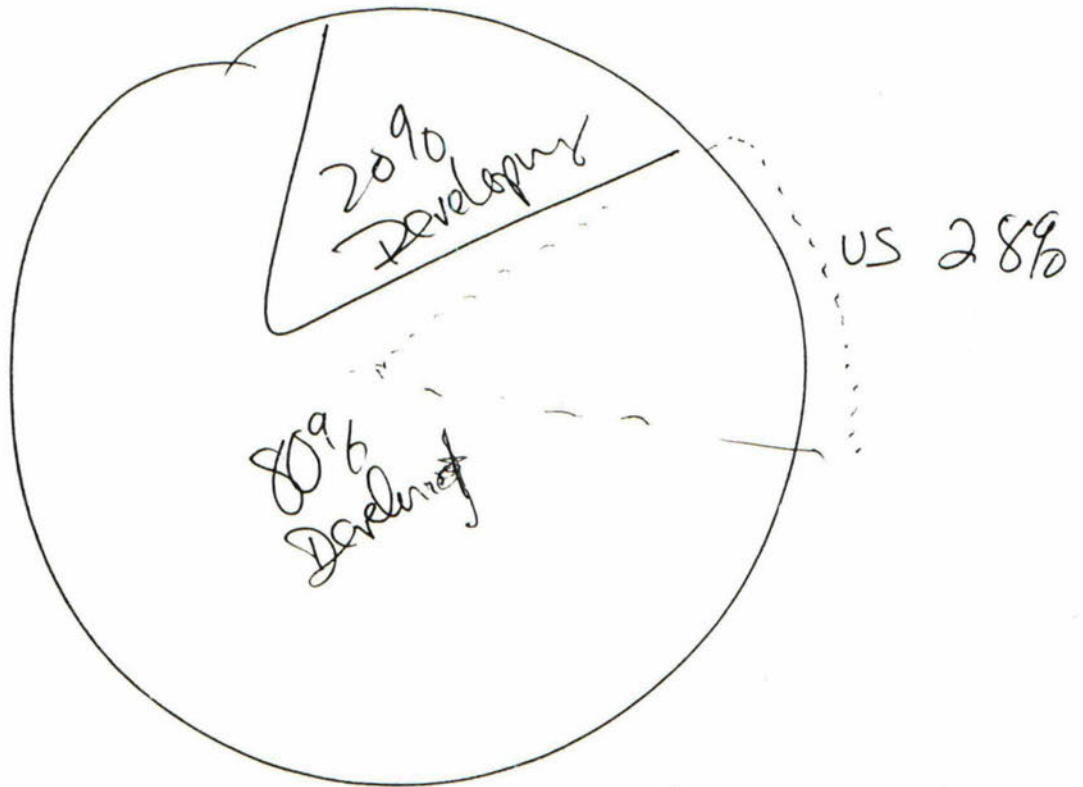
Up to present only

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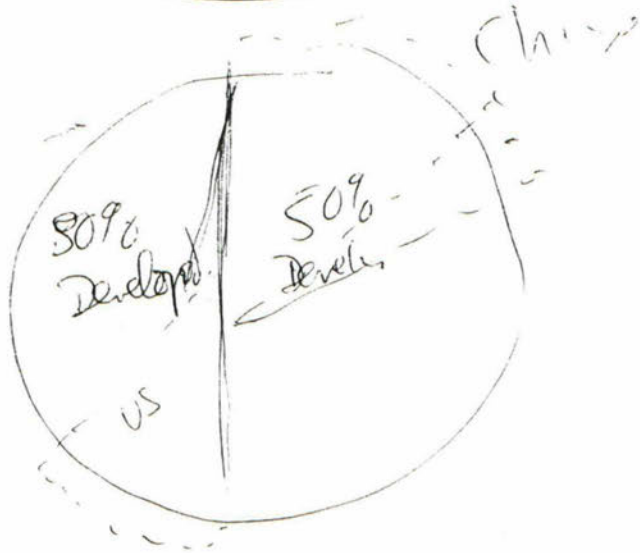


6

1950-1990



2035



Global Average Temperature

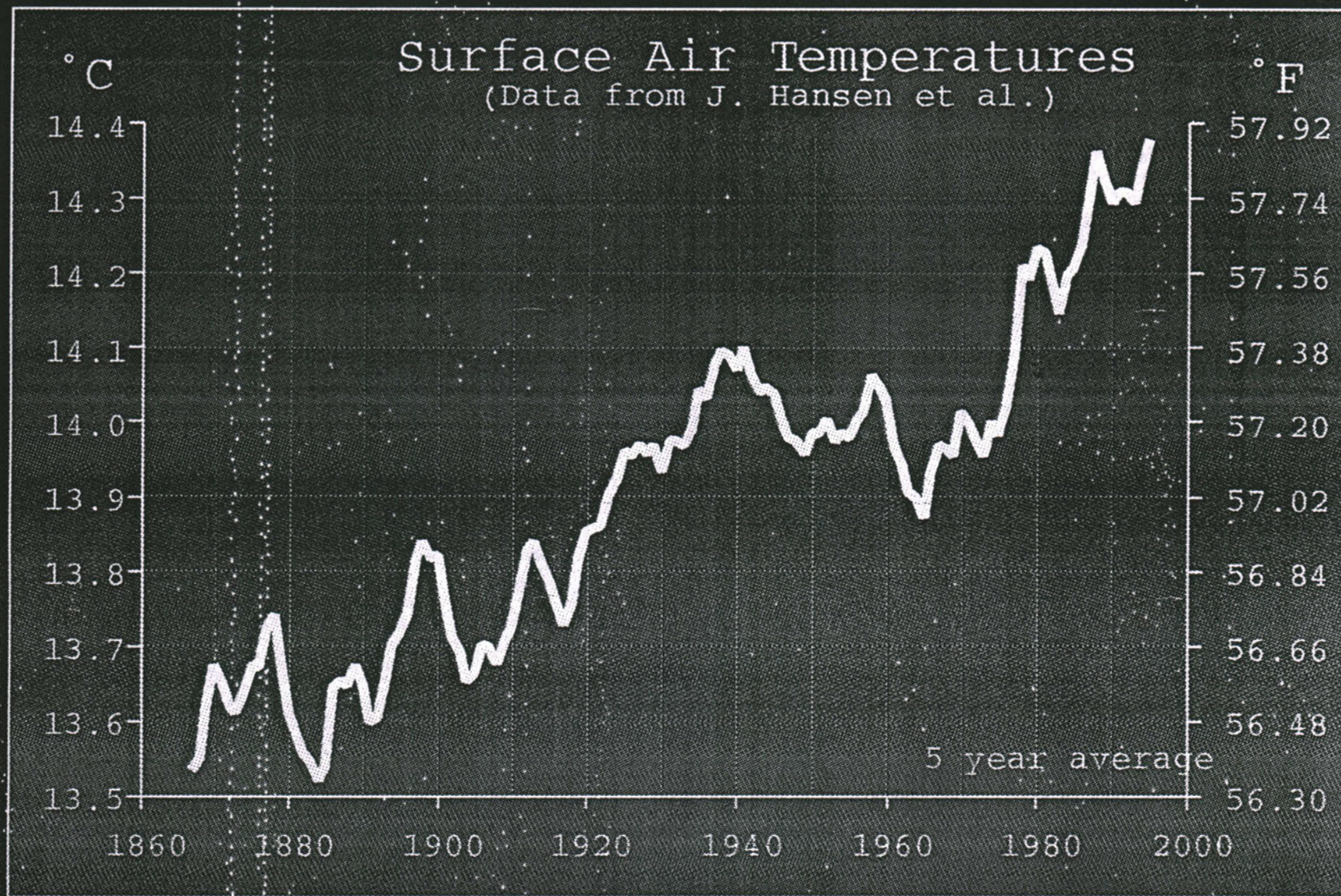


Figure 8

Photograph & image

of
Flood

Figure 9

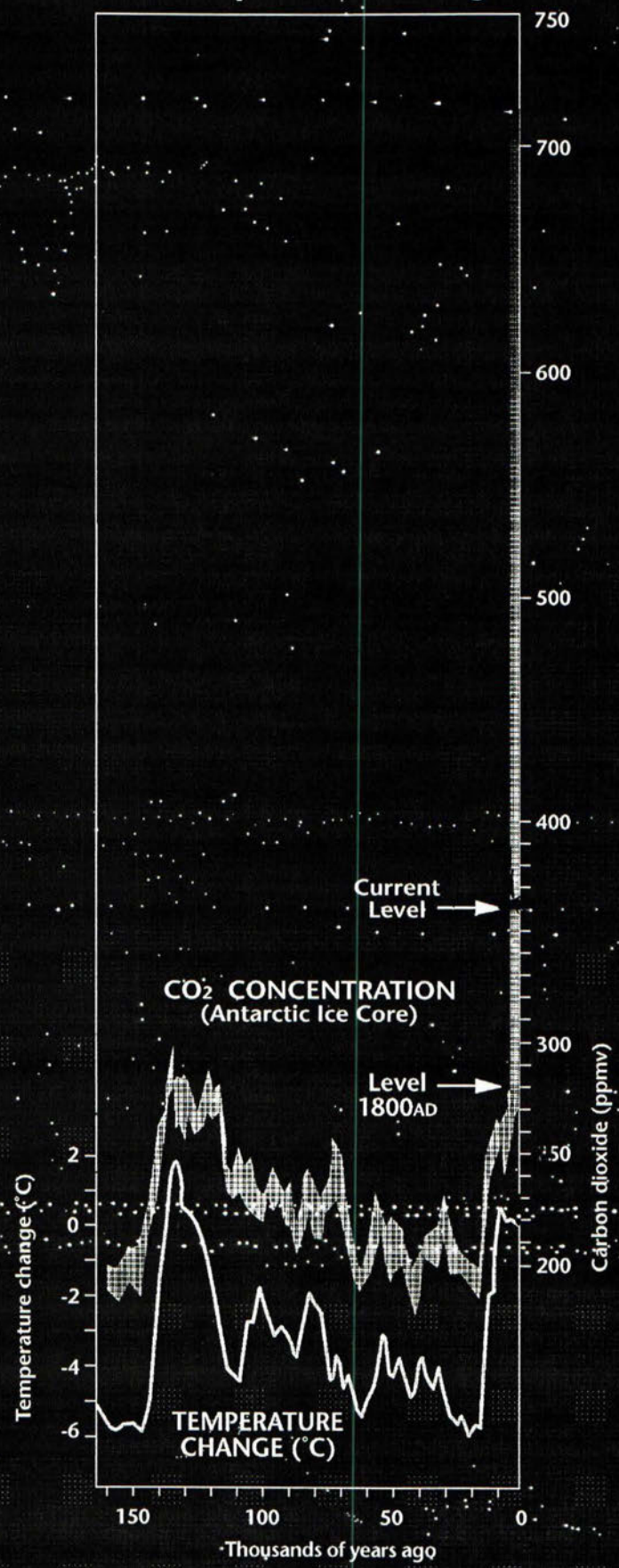
Photograph of

Permafrost melting

ie- Slumping road

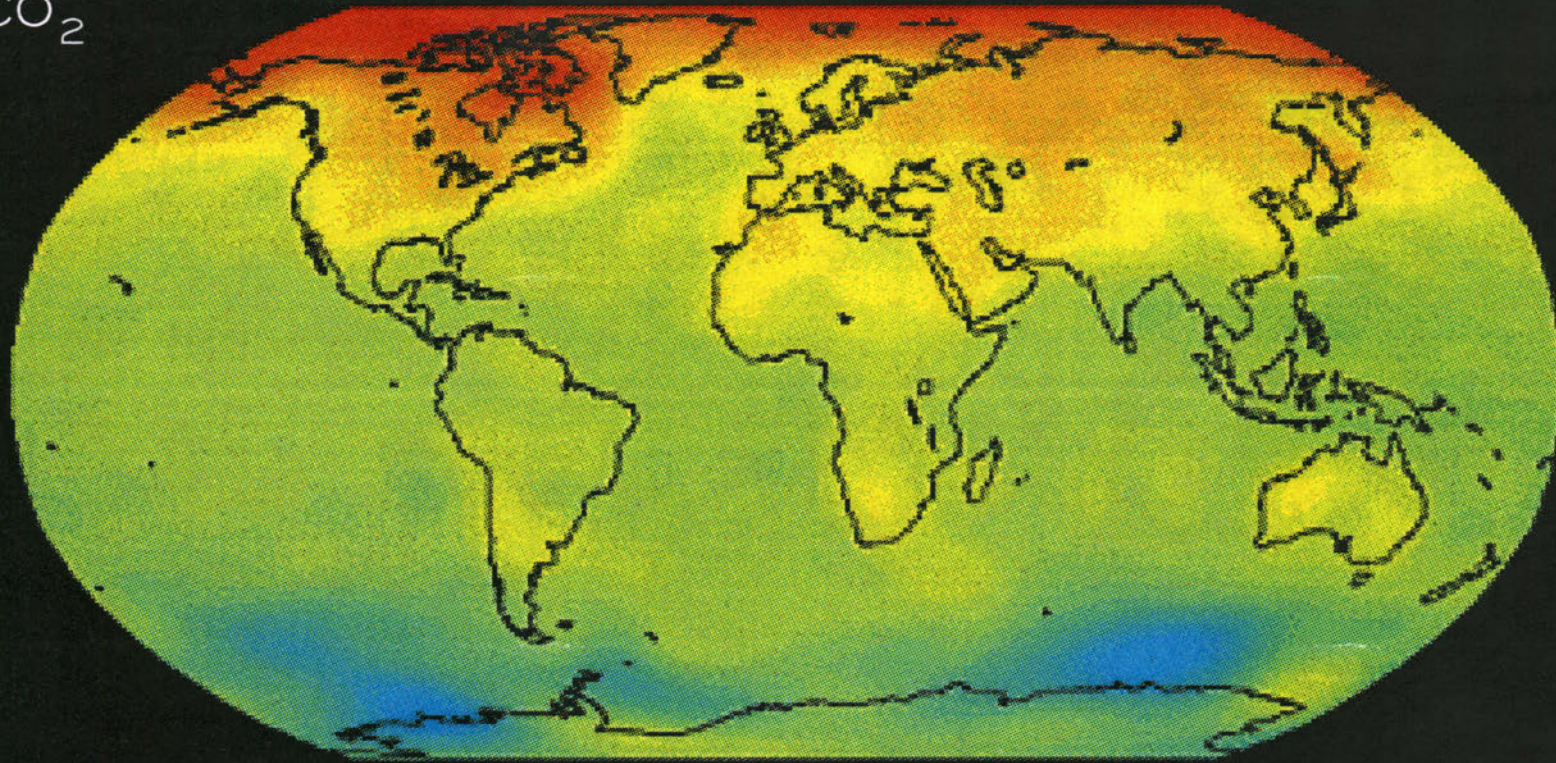
or forest slumping (ie- Ask Gunter Weller)

Atmospheric Carbon Dioxide Concentration and Temperature Change



SURFACE AIR WARMING ($^{\circ}\text{F}$)

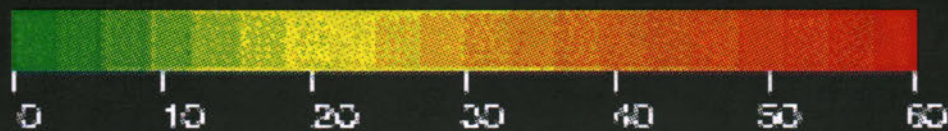
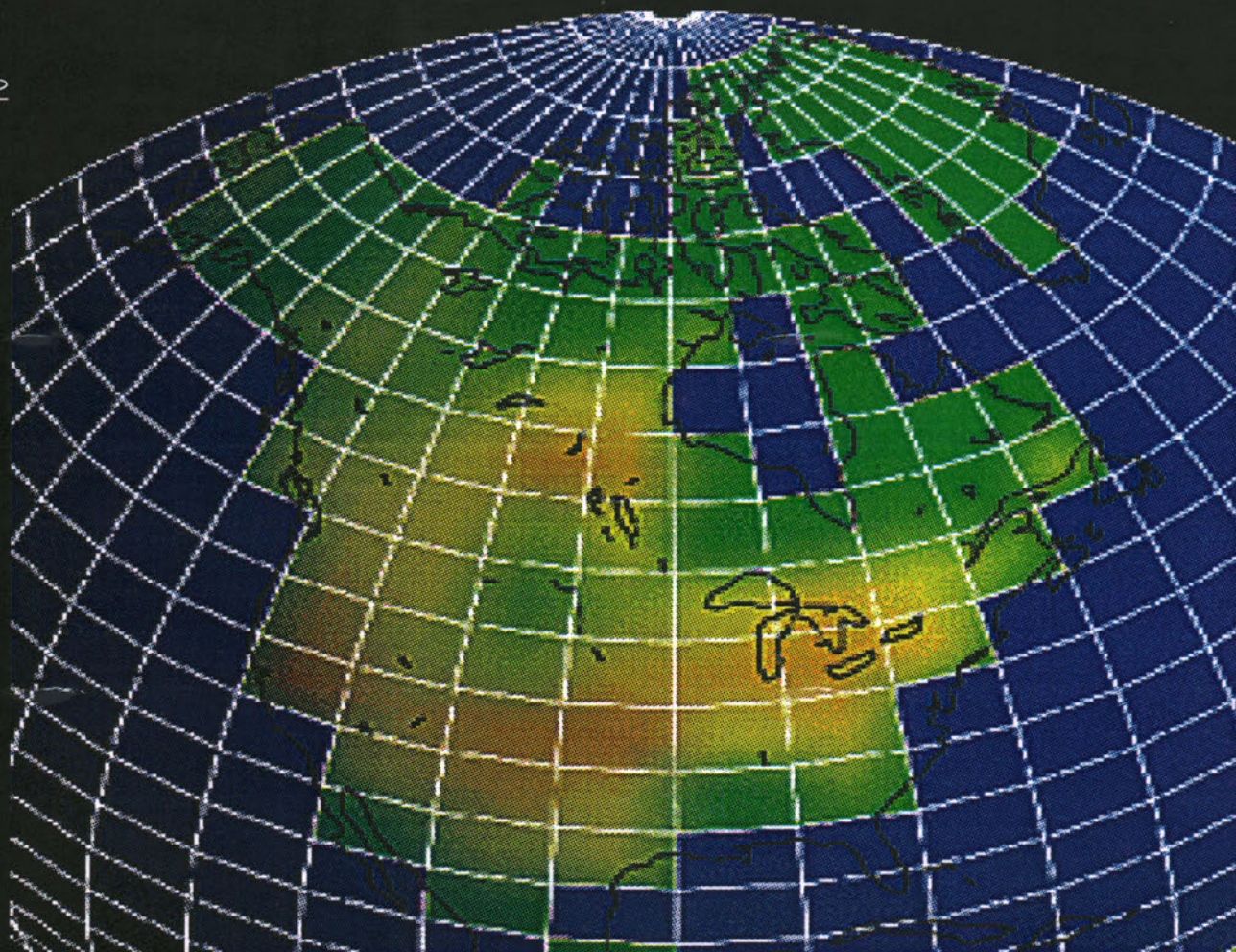
$2\times\text{CO}_2$



SOURCE: GFDL R15 CLIMATE MODEL; CO_2 TRANSIENT EXPERIMENTS, YEARS 401-500

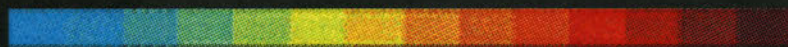
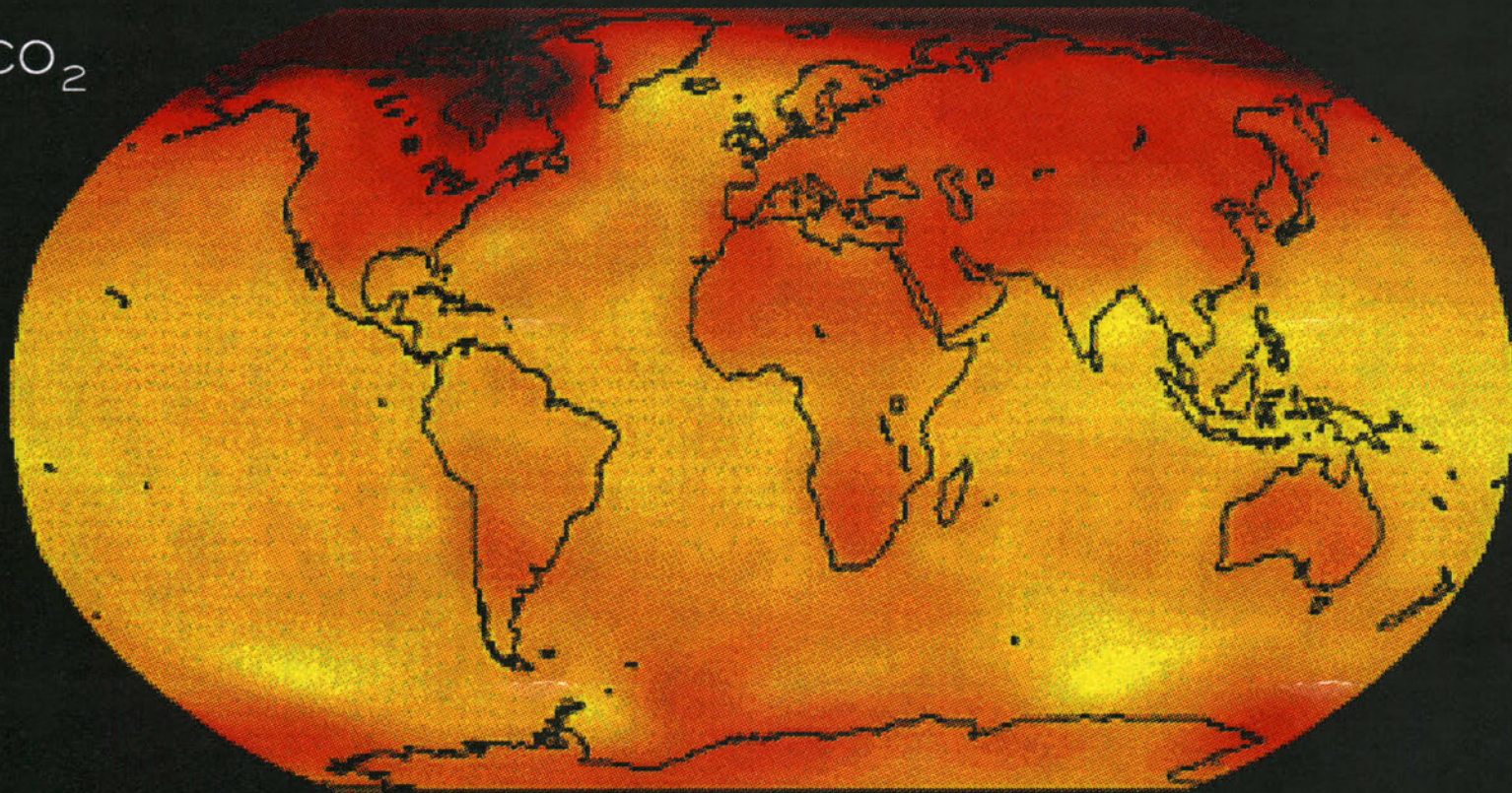
PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

2xCO₂



SURFACE AIR WARMING (°F)

4xCO₂



-5 0 5 10 15 20 25

SOURCE: GFDL R15 CLIMATE MODEL; CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

4xCO₂

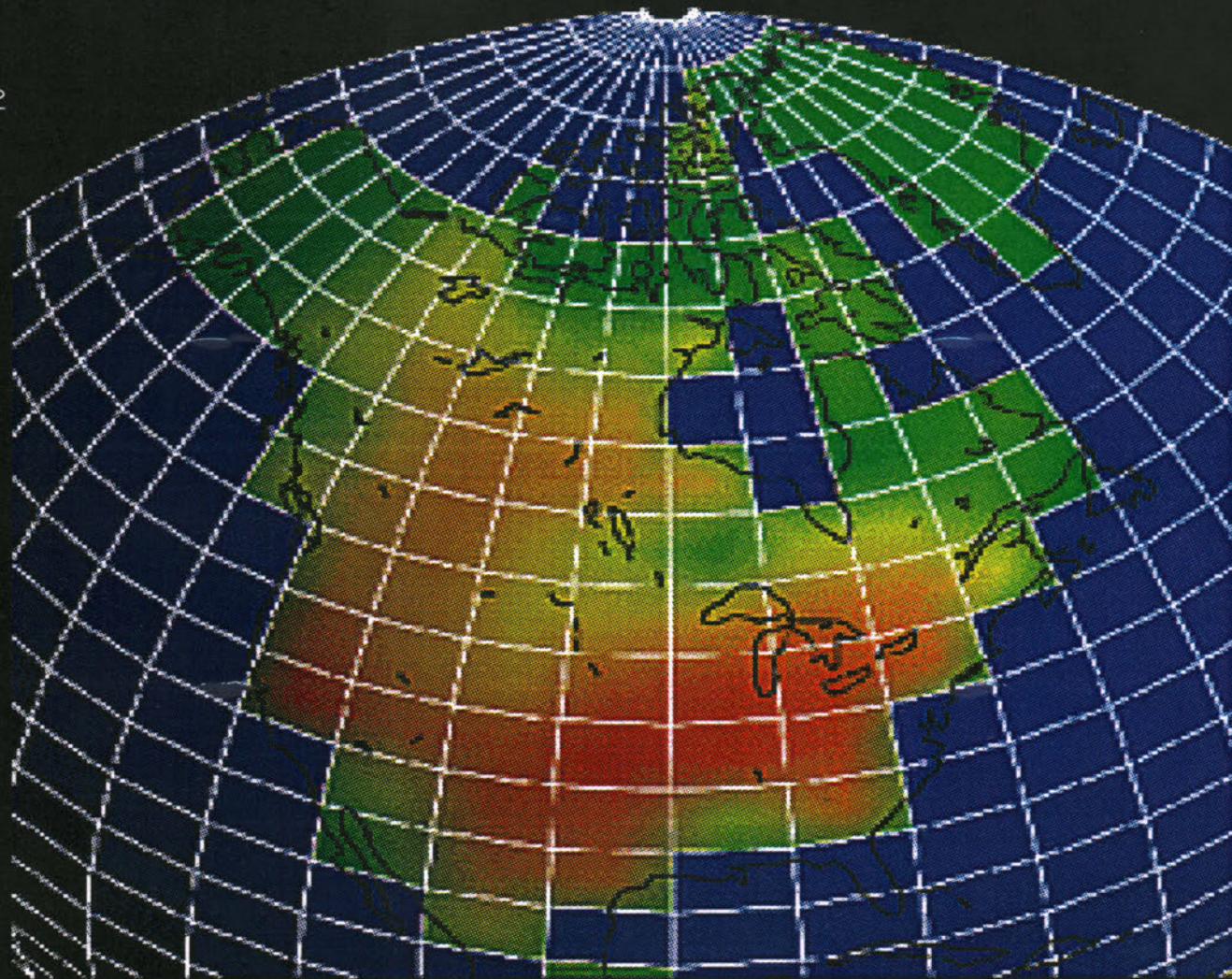


Figure 15

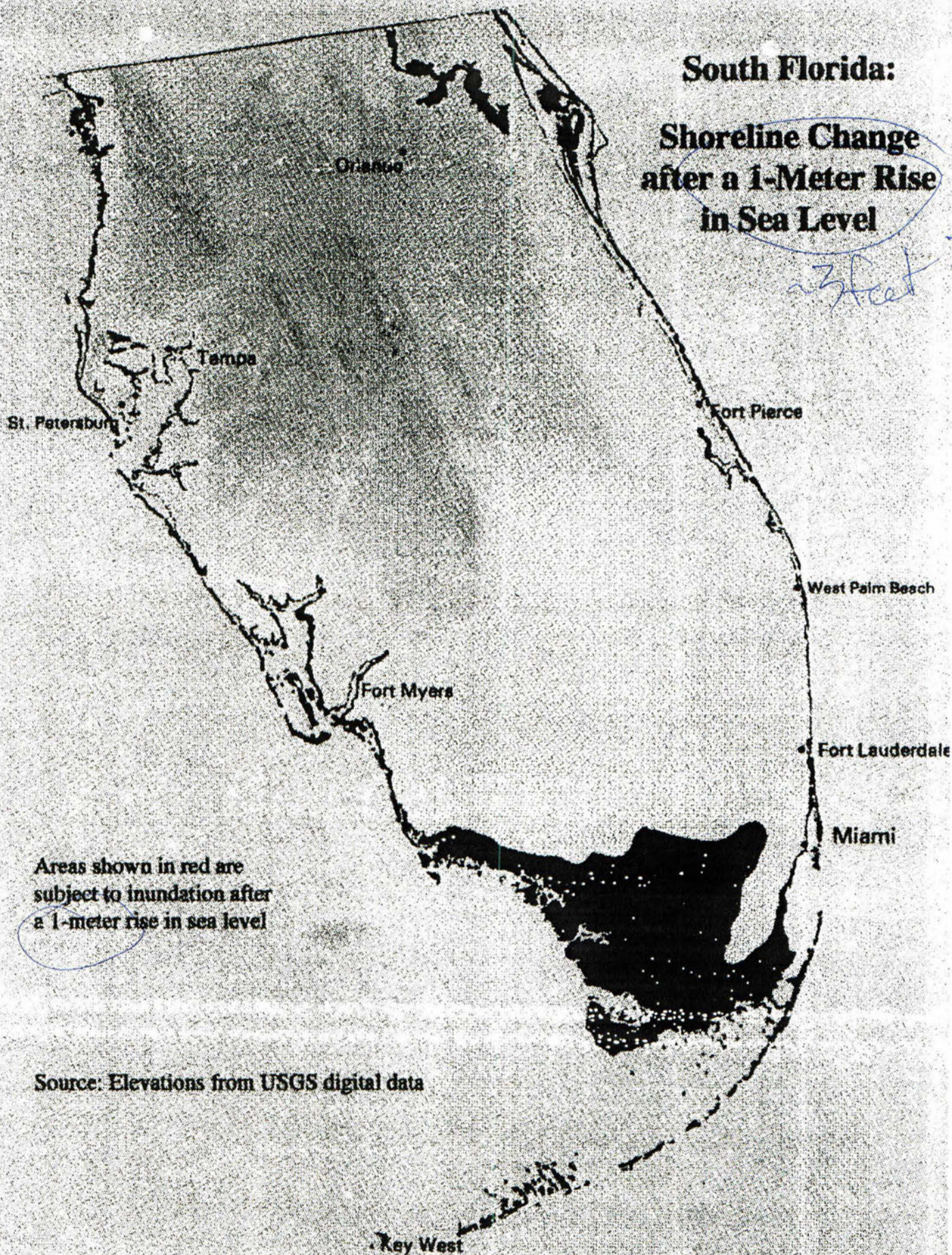
Photograph

of urban smog

South Florida:

Shoreline Change after a 1-Meter Rise in Sea Level

~3 feet



Areas shown in red are
subject to inundation after
a 1-meter rise in sea level

Source: Elevations from USGS digital data

Prepared by the U.S. Geological Survey, 1997

Fig. 17

Photo of dry

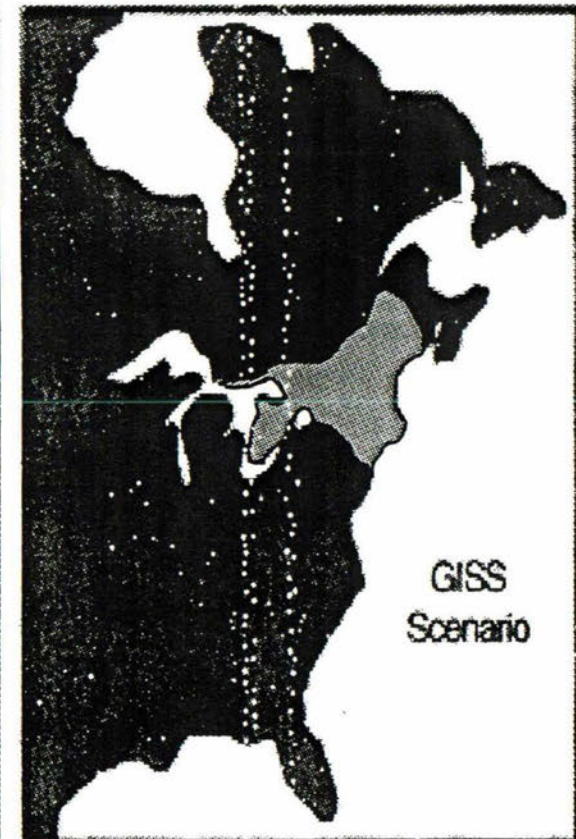
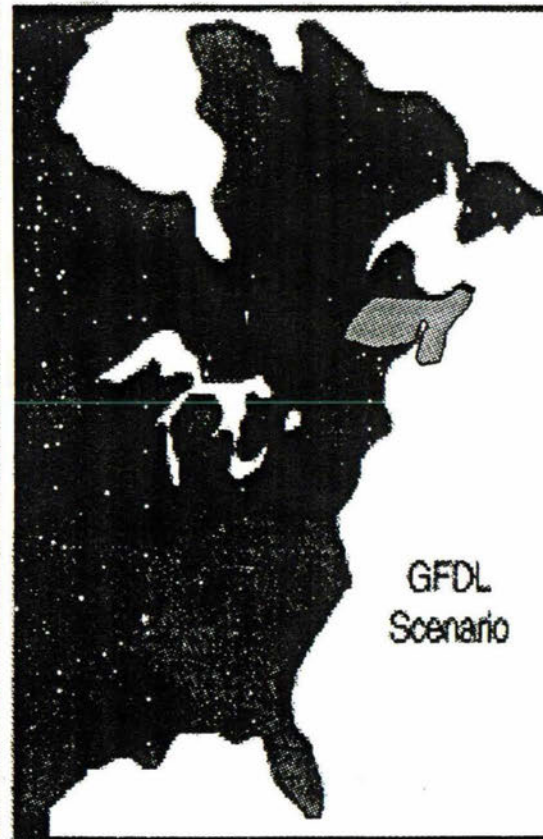
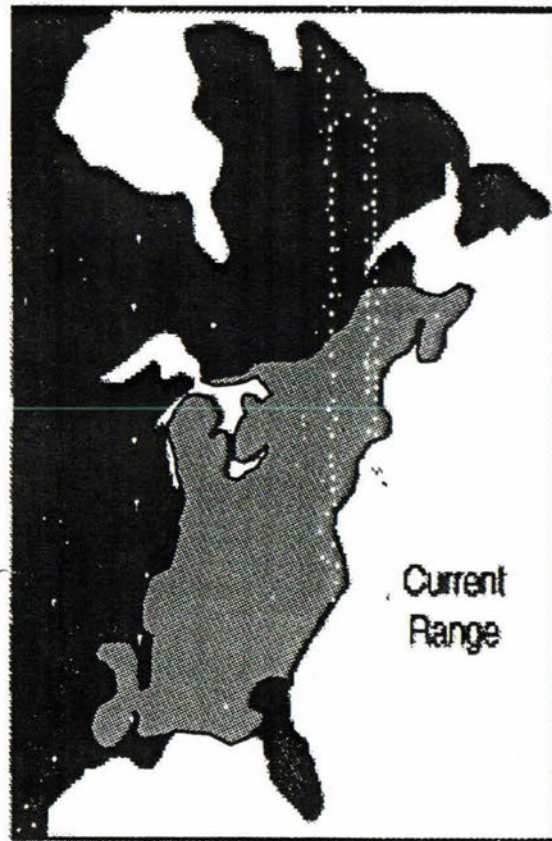
River bed

(U. Minn) call Margaret Davis

use Sugar maple

18

CURRENT AND PROJECTED RANGES OF BEECH TREES IN THE U.S. UNDER TWO MODEL SCENARIOS



Current Growth



Projected New Growth

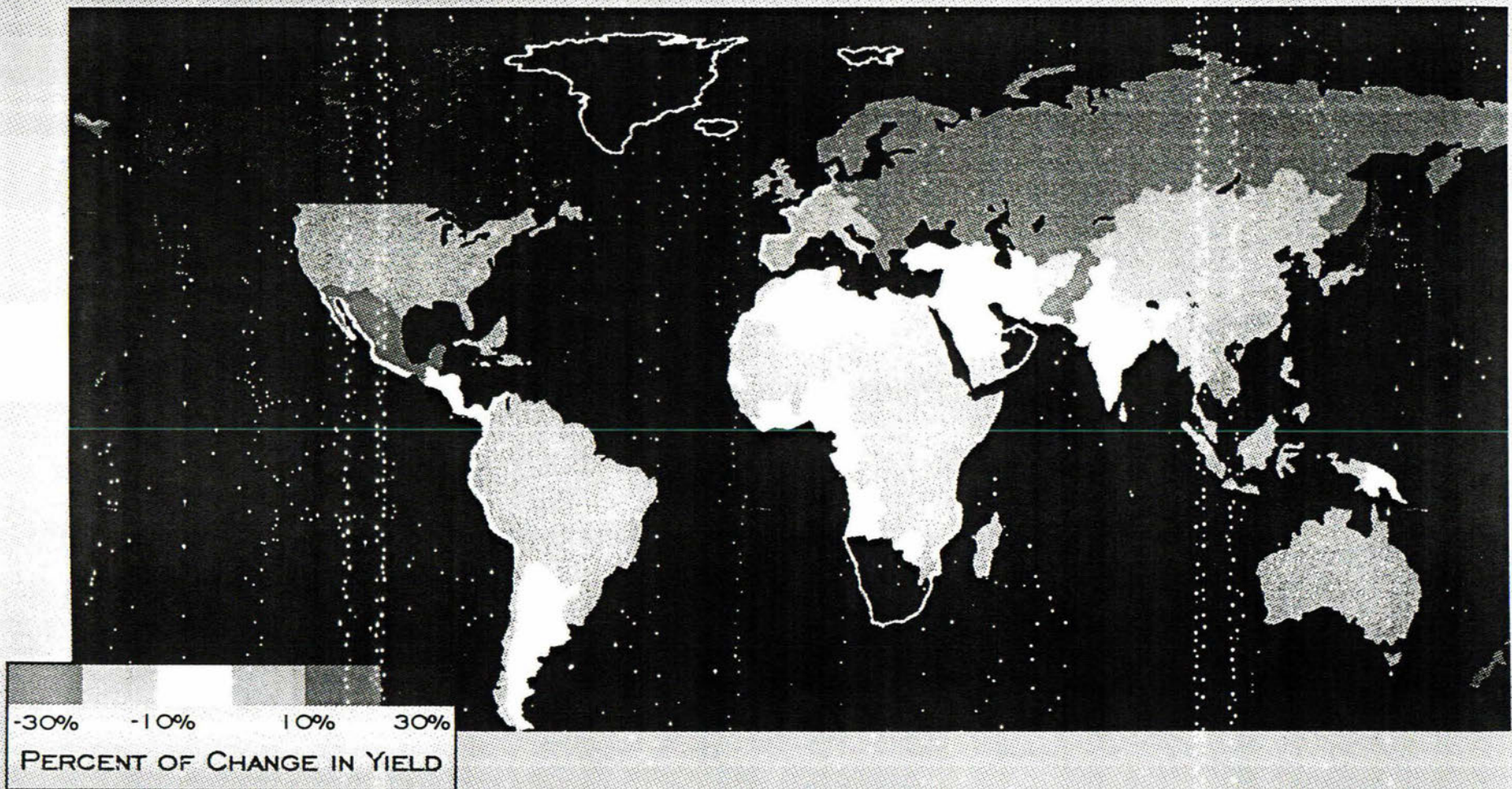
(17/80)

GLACIER SHRINKAGE IN GLACIER NATIONAL PARK

1850 - 1993



AGRICULTURAL RESOURCES: POTENTIAL CHANGE IN GRAIN YIELD DUE TO DOUBLED CO_2



BASED ON GISS MODEL; PHYSIOLOGICAL CO_2 EFFECTS INCLUDED

SOURCE: ROSENZWEIG AND HILLEL (1993)

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GLOBAL CLIMATE CHANGE

AN EAST ROOM ROUNDTABLE

The White House

July 24, 1997

Climate Change

July
1996

State of Knowledge

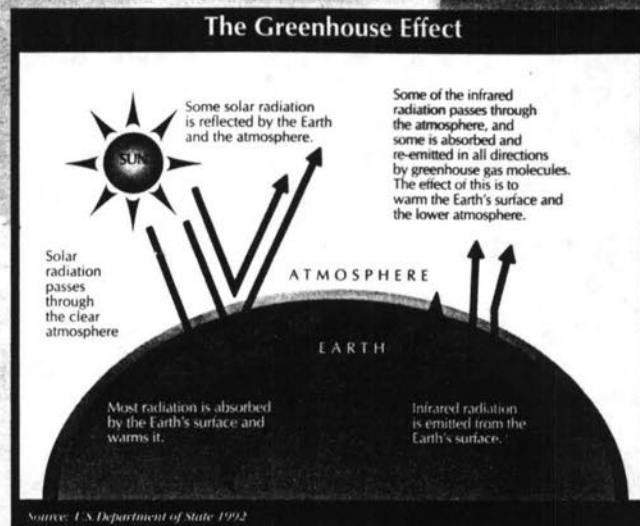
The Earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere. The buildup of greenhouse gases—primarily carbon dioxide, methane, nitrous oxide and chlorofluorocarbons—is changing the radiation balance of the planet. The basic heat-trapping property of these greenhouse gases is essentially undisputed. Although there is considerable scientific uncertainty about exactly how and when the Earth's climate will respond to enhanced greenhouse gases in the future, observations indicate that detectable changes are underway. The direct effects of climate change will include changes in temperature, precipitation, soil moisture and sea level. Such changes could have adverse effects on ecological systems, human health and socio-economic sectors.

Human-induced climate change is a complex problem, which can impact the economy and the quality of life for this and future generations. The lag time between emission of the gases and their impact is on the order of decades to centuries; so too is the time needed to reverse any effects. Thus, policy decisions in the near term will have long-term consequences.

The Climate System

A natural greenhouse effect keeps the Earth about 33°C (60°F) warmer than it otherwise would be. Without this greenhouse effect, life as we know it would not be possible. Water vapor, carbon dioxide and other trace gases trap heat as it is re-radiated from the Earth back to space. However, since pre-industrial times, human activities have added to the natural greenhouse effect by releasing additional greenhouse gases to the atmosphere. The burning of fossil fuels (coal, oil and gas) for energy is the primary source of emissions; changing land-use patterns through agriculture and deforestation also contribute a significant share. Current global emissions of carbon dioxide from energy use are approximately 6 gigatons of carbon (GtC) per year.

Future greenhouse gas emissions are sensitive to changes in demographic, economic, technological, policy and institutional developments. By the year 2025, world emissions could range from 8 to 15 GtC per year. In the year 2100, world emissions are projected to range from 5 to 36 GtC per year, depending on energy use, populations, technologies and other factors. The United States and the rest of the OECD countries currently

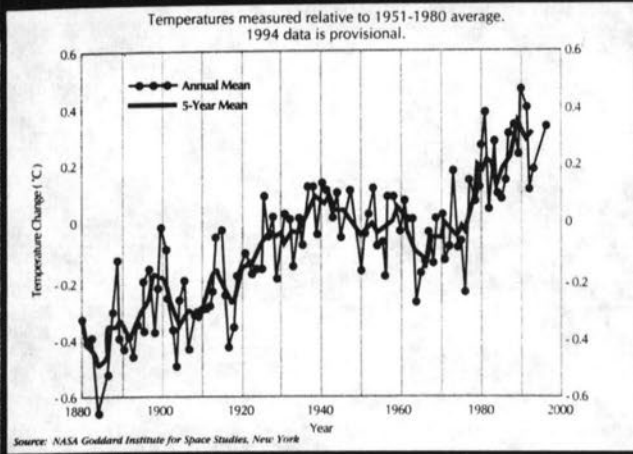


contribute about 40 percent of global carbon dioxide emissions. Future growth in emissions from OECD countries is predicted to be significantly smaller than growth in developing countries and countries with economies in transition.

Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased by nearly 30 percent, methane concentrations have doubled and nitrous oxide concentrations have risen by 15 percent. These increases result in a radiative forcing or heat-trapping of energy equivalent to about 2.8 watts per square meter (Wm^{-2}). About half of the radiative forcing may have been masked by increased levels of traditional air pollutants—sulfates and carbonaceous aerosols, particularly in the northern hemisphere—which cool the atmosphere by reflecting incoming solar radiation and altering the reflective properties of clouds. Aerosols are short-lived and vary regionally, hence they should not be regarded as a simple offset to greenhouse gas forcing. In addition, due to their health effects, buildup will likely be limited. Calculations suggest that the projected increases in atmospheric concentrations of greenhouse gases alone will result in an additional radiative forcing of about $3\text{--}8 \text{ Wm}^{-2}$ by 2100. For a given concentration of greenhouse gases, the resulting increase in radiation can be predicted with precision; but the resulting impact on climate is more uncertain.

Model calculations, based on plausible ranges of future emissions and climate sensitivities, suggest that the global surface temperature could increase an average of 1.0–3.5°C (1.8–6.3°F) by 2100, with significant variation by region. This estimate accounts for the offset from aerosols, which has lowered earlier estimates somewhat. Global-average temperature changes of this magnitude would be greater than

Observed Global Surface Air Temperature



recent natural fluctuations and would occur at a rate significantly faster than any observed changes in the last 10,000 years. The United States and high latitudes are projected to warm more than the global average, especially as sulfate aerosol loading is decreased.

Model calculations also suggest that the rate of evaporation will increase as the climate warms, leading to an increase in average global precipitation. Although precipitation at high latitudes is expected to increase, much of the precipitation increase may fall over the oceans. The models also suggest that the frequency of intense rainfall will increase and there will be a marked decrease in soil moisture over some mid-latitude continental regions during the summer.

Sea level is projected to increase by 15 to 95 centimeters (6 to 38 inches) by the end of the next century, due primarily to the thermal expansion of the oceans and the melting of glaciers.

Calculations of climate change at the regional scale are significantly less reliable than average global values, and it is unclear whether climate will become more variable. The frequency and intensity of some extreme weather events of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency of hot or cold spells, and the intensity of associated fire and pest outbreaks) could increase.

Global mean surface temperatures have increased between 0.3 and 0.6°C (0.54 and 1.08°F) since the late 19th century, despite marked regional, seasonal and diurnal differences, raising the decade global temperatures to the highest level in this century.

The ten warmest years this century have all occurred since 1980. 1995 was the warmest year on record, suggesting the atmosphere has rebounded from the transient cooling of 0.5°C (0.9°F) caused by the eruption of Mt. Pinatubo and simulated by the models.

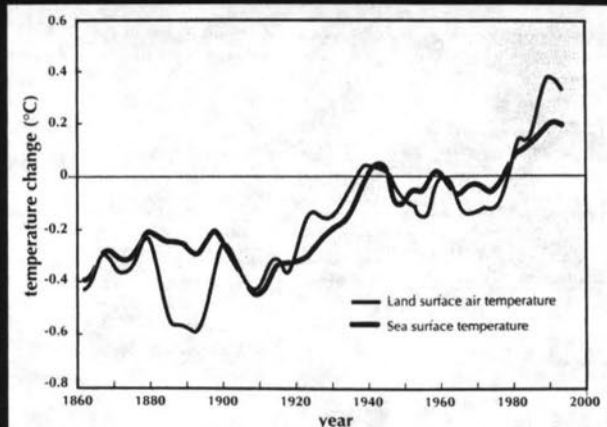
Several ancillary pieces of evidence consistent with warming, such as a decrease in Northern Hemisphere snow cover, a simultaneous decrease in Arctic sea ice, continued melting of alpine glaciers and a rise of sea level have been corroborated. The frequency of extreme rainfall events also has increased throughout much of the country, suggestive of an intensification of the hydrologic cycle.

There is consistency between the observed global average temperature trend over this period and model simulations of the warming due to greenhouse gases if allowance is made for the increasing evidence of a cooling effect due to anthropogenic aerosols and stratospheric ozone depletion. Analyses of the geographical and vertical patterns of change give us more confidence that we are beginning to detect a human-induced signal despite natural climate variability. The IPCC concludes "the balance of evidence suggests a discernible human influence on global climate."

Carbon cycle models imply that limiting atmospheric concentrations of carbon dioxide to any level below 750 parts per million by volume (ppmv), about three times the pre-industrial level, would require emissions worldwide to eventually drop below 1990 levels. The longer emissions continue to increase, the greater the eventual reductions would have to be in order to stabilize concentrations at a given level.

Although much is already known about the greenhouse effect, substantial reduction of key uncertainties (detailed quantification of the timing, magnitude and regional patterns of climate change) may require a decade or more. Accurate predictions are limited by our knowledge of the future emissions and atmospheric concentrations of carbon dioxide, aerosols and other greenhouse gases, the role of clouds and water vapor, and the role of the oceans and land ecosystems.

Observed Land and Sea Surface Air Temperature



Land Surface Air and Sea Surface Temperatures, 1861-1994 (IPCC, 1995)

Projected Impacts of Climate Change

Climate change poses threats to resources both domestically and internationally. These threats could have significant, but uncertain, socioeconomic consequences. Changes in temperature, precipitation and sea level driven by climate change can add to existing stresses on resources caused by other influences such as population growth, land-use changes and pollution. Developing countries are more vulnerable than developed countries to climate change because of their socioeconomic conditions.

Overall, various strategies for coping with climate change can be identified for "intensively managed" systems (such as agriculture, water resources and developed coastlines). For these systems, technological and management options exist to some extent today, although they may be costly to implement. With time, more efficient responses can be developed for these sectors. By comparison, fewer options can be identified for natural systems (such as wetlands and wilderness areas).

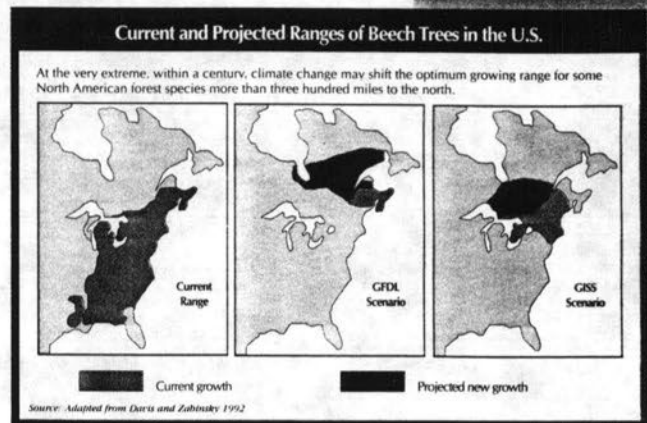
Natural ecosystems will be degraded because the composition, geographic distribution and productivity of many ecosystems will change as individual species respond to changing climate. This will likely lead to reductions in biological diversity and in the goods and services ecosystems can provide for society.

Temperature changes of the magnitude expected from the enhanced greenhouse effect have occurred in the past, but the previous changes took place over centuries or millennia instead of decades. Rates of natural migration and adaptation of species and communities appear to be much slower than the predicted rate of climate change.

One of the consequences of global climate change may be increases in the frequency of some extreme weather events, particularly droughts and floods. Of course, we cannot unambiguously relate climate change to specific events. However, these events, when they do occur, can be costly. For example:

- Since 1992, 15 weather-related disasters in the United States have cost \$70 billion in damages and several hundred deaths from floods, heat waves, hurricanes, blizzards and hail storms.
- Damages from the Mississippi River flooding in 1993 are estimated to range from \$10 billion to \$20 billion.
- Almost \$4 billion in federal payments went to farmers suffering crop losses during the 1988 drought.

Examples of the kinds of effects that may result from climate change include:



Health

Human health will be adversely affected through an increase in the rate of heat-related mortality and in the potential for the spread of vector-borne diseases such as malaria, dengue fever, yellow fever and encephalitis and non-vector borne-diseases such as cholera and salmonellosis.

There will likely be increased risk of malaria and dengue fever in the United States. Changing temperatures and precipitation patterns may produce new breeding sites for pests and pathogens.

Climate change may increase heat-stress mortality, particularly in the very young and very old.

Water Resources

Changes in precipitation and increased evaporation from higher temperatures can affect water supplies and water quality, posing threats to hydropower, irrigation, fisheries and drinking water.

Floods are more likely because the frequency of intense rainfall is predicted to increase.

Droughts are likely to be more severe because warmer temperatures increase evaporation rates and thereby lead to drier soils during periods of little or no rain.

Climate change would be likely to add to the stress in several United States river basins such as the Great Basin, California, Missouri, Arkansas, Texas Gulf, Rio Grande and Lower Colorado.

Water scarcity in Middle Eastern and African countries also is likely to be exacerbated by climate change.

Coastal Resources

A 50 centimeters (20 inches) rise in sea level by the year 2100, which is within the range projected by the IPCC, could inundate more than 5,000 square miles of dryland and an additional 4,000 square miles of wetlands in the United States if no protective actions are taken.

Areas at highest risk from sea level rise are areas currently experiencing high erosion rates and those with very low elevations, such as parts of the United States Atlantic and Gulf coasts.

Internationally, many low-lying areas such as parts of the Maldives, Egypt and Bangladesh would be completely inundated and uninhabitable by a similar sea level rise. This would create large numbers of environmental refugees which would put stress on governments and social structures.

Agriculture

Large areas of the eastern and central United States face moderate to severe drying. Drought could become more frequent, particularly in the Great Plains.

Agriculture production in developing countries is likely to be more vulnerable to climate change, given that these countries have relatively fewer economic resources.

Food scarcity is threatened in some regions of the world, especially in the tropics and subtropics, where many of the world's poorest people live, even though the effects of climate change on total global food production may be small to moderate compared with the effects of population growth and increasing nutrition demands.

Forests

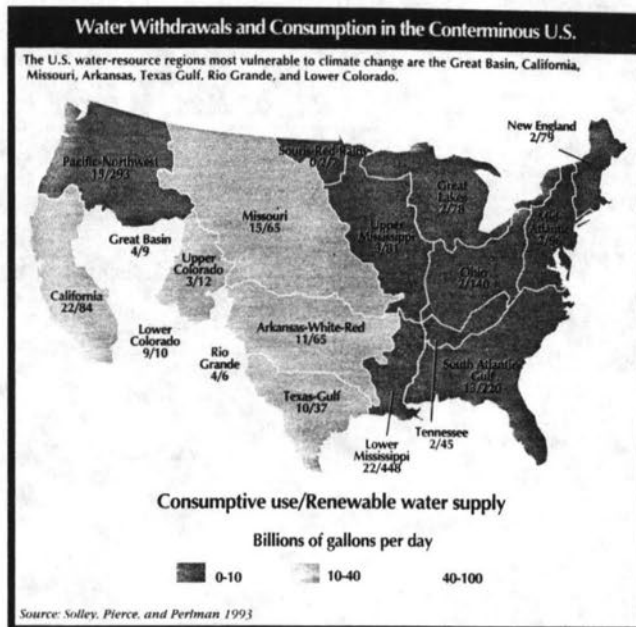
Climate change over the next several decades might shift the ideal range for some North American forest species by as much as 300 miles to the north, exceeding the ability of forests and other ecological communities to migrate.

Forest damage from fire and diebacks driven by drought, insects and disease could increase.

The most vulnerable forest resources are those in regions subject to increased moisture stress, as in the dry continental interiors.

Socio-Economic Analyses

Socio-economic analyses of climate change also are making important contributions. A key insight is that a portfolio of actions aimed at mitigation, adaptation and improving our knowledge would be a prudent way to deal with climate change. It is important to allow activities to be adjusted periodically in light of new information. Another insight is that policy analysis and development must carefully consider both the potential costs of inaction in terms of impacts, as described in the previous section, and the potential economic



costs associated with measures to reduce greenhouse gas emissions.

From the practitioners' perspective, qualitative insights from mitigation cost modeling studies are more important than the absolute numerical results. For example, specific approaches, designs and strategies may emerge as superior when evaluated using a variety of modeling frameworks. Several distinct methodologies are among the tools available to assist policy-makers in evaluating the potential costs associated with reductions in greenhouse gas emissions. These include: technology costing studies, economy-wide macroeconomic models and computable general equilibrium models. The various models each have strengths and weaknesses, and none by themselves can adequately portray the potential economic impacts associated with reductions in greenhouse gas emissions.

Analyses to date highlight the key role of technology innovation, capital stock turnover and capital productivity and their influence on mitigation costs. In addition, recent analyses also suggest that flexible approaches, including the possibility of optimizing reductions across countries and over time, have the potential to significantly reduce the costs of achieving any given mitigation objective.

Source: Office of Science and Technology Policy, 1996

Climate Change: State of the Knowledge Brochure

Covers:

Front: Earth picture (maybe one that shows how thin the atmosphere is)
Title

Inside: Text on climate change research programs: USGCRP, IPCC, IGBP, etc.

Back: Biosphere (the Living Earth)

Body:

Opening (abstract)

The Greenhouse Effect and Historical Emissions

Climate Change Over the Last 100 years

Climate Change Over the Next 100 years

Vulnerabilities and Potential Consequences

Opening ("Abstract")

The Intergovernmental Panel on Climate Change recently stated that the balance of the scientific evidence now suggests that there is "a discernible human influence on global climate." The Earth's climate system is already experiencing rates of change faster than any during the last 10,000 years, the period in which modern civilization developed. The Panel estimated that an increase in global surface air temperature of about $3\frac{1}{2}^{\circ}\text{F}$ is likely by the year 2100, although the change could be as low as 2 and as high as $6\frac{1}{2}^{\circ}\text{F}$, depending on what the countries of the world do to control their emissions of carbon dioxide (CO_2) and other greenhouse gases in the intervening years.

The ultimate aim of the Framework Convention on Climate Change is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system." This level should be achieved soon enough to (1) allow ecosystems to adapt naturally to climate change, (2) ensure that food production is not threatened, and (3) enable sustainable economic development to proceed. While much work remains to be done to improve the precision of impact assessments, the risks of climate change are becoming increasingly apparent, and lend support for the idea that measures for mitigation and adaptation are warranted.

The Greenhouse Effect and Historical Emissions

Life as we know it is possible on Earth because of a natural greenhouse effect that keeps our planet about 60°F warmer than it otherwise would be. (Figure 1: Greenhouse effect) Water vapor, carbon dioxide (CO₂), and other trace gases, such as methane and nitrous oxide, trap heat and keep it from being lost by re-radiation back to space. With industrialization, the amounts of greenhouse gases added to the atmosphere by human activities have become significant. On a global scale, burning of coal, oil, and natural gas releases about 6 billion tons of carbon into the atmosphere each year. Land-use change, predominantly the clearing of forests for agriculture, contributes about 1-2 billion tons more per year globally. (Figures 2 and 3: Smokestacks; deforestation photos) The consequence is that there has been a steady increase in greenhouse gas concentrations in the atmosphere.

Since 1860, CO₂, the most important human-derived greenhouse gas, has increased 30%, from 280 to 360 parts per million (*Figure 4: CO₂ record, 1860 to present*). Methane concentration has also more than doubled, and nitrous oxide has risen by 15%. Over a much longer time scale, there is a clear relationship between CO₂ levels and the global temperature record. Fluctuations of CO₂ and temperature have closely mirrored each other over the last 160,000 years. (Figure 5: CO₂ and temperature record over last 160,000 years as measured in ice cores)

Whose emissions are in the atmosphere? From 1950 to 1990, 80% of total CO₂ emissions came from the developed countries, with the United States the largest single source. (*Figure 6: 1950-1990 vs 2035 pie charts*). More recently, the developing countries' share of emissions from the burning of fossil fuels has grown from a mere 20% to about 35%. Over the next few decades, 90% of the world's population growth will take place in the developing countries, which will account for 50% of total global emissions by 2035 if current trends continue. China, which has already become the second largest source, will displace the U. S. as the largest emitter. Per capita energy use in the developing countries, which is currently only 1/10 to 1/20 of our level, will also increase.

Climate Change Over the Last 100 years

What has happened to date? The Intergovernmental Panel on Climate Change's Second Assessment Report in 1995 described a series of changes that have already been observed. Over the last century, the average surface temperature of the Earth has increased by about 0.5 - 1.0 °F, which is as high or higher than it has been in any century since at least 1400 AD. The eleven warmest years this century have all occurred since 1980, with 1995 the warmest on record. (*Figure 7: Global average temperature*) Critics have pointed to an apparent discrepancy between the long term surface temperature measurements and the short term satellite observations of the atmosphere, maintaining that the satellite observations actually show that the Earth is cooling. The two techniques measure different aspects of global temperature, and both are influenced by a variety of factors, such as the presence of local pollution. When the satellite record is corrected for an unusual warming at its start (due to an El Niño) and an unusual cooling at its end (due to the eruption of the volcano, Mt. Pinatubo), warming temperatures since the late 1970s are evident in both, although rates are slightly different.

What does warming do? A warmer earth essentially speeds up the global water cycle. Because there is more evaporation at higher temperatures, there is more water in the atmosphere that will come down as rain or snow. We may be seeing the first signs of a change in the water cycle - since the beginning of the century, precipitation in the U. S. has increased by about 6%, with about a 20% increase in the frequency of intense precipitation events, or heavy downpours. Such events lead to flooding, soil erosion, and even loss of life. (*Figure 8: Flood picture*) But in some midcontinental areas, warming increases evaporation and leads to drought.

There is also evidence that regional ecosystems are responding to warming. Between 1981 and 1991, the length of the growing season in the northern high latitudes (between 45° and 70° N) increased by a total of up to 12 days. "Greening" in spring and summer occurred up to eight days earlier, and vegetation continued to photosynthesize an estimated 4 days longer. There also appeared to have been approximately a 10% increase in carbon uptake by plants, possibly due to the longer growing season and a CO₂ fertilization effect.

Sea level is also rising, due primarily to thermal expansion of the oceans and the melting and retreating of ice in glaciers and ice caps. Over the last century, global mean sea level has risen 4 to 10 inches (10 -25 cm). [Add text on permafrost.] (*Figure 9: Permafrost melting photo*) During this century, mountain glaciers have already retreated world-wide.

Climate Change Over the Next 100 years

Where are we headed? Even if it were possible to stabilize the rate at which CO₂ is flowing into the atmosphere, it would continue to accumulate and its concentration continue to rise throughout the next century and beyond. If the world proceeds on a “business as usual” path, it is likely that we are headed for an atmospheric CO₂ concentration of more than 700 ppm by 2100, about double the current level. (Figure 10: VP chart with future added on) Predictions from General Circulation Models (GCMs) are for an ensuing 2-6° F rise in global temperature over the next century - a rate of change not seen on the planet at least the last 10,000 years.

What are the projected extent and pattern of warming over the globe? In a world with a CO₂ concentration of 560 ppm, a 5 to 10° F change for the U. S. will not be evenly distributed, but will be amplified at the higher latitudes. (Figure 11: 2xCO₂ surface air warming) These warmer temperatures would lead to soil drying in some regions, with moisture deficits estimated at 10 to 30% for the U. S. (Figure 12: 2xCO₂ reduction in soil moisture)

But there is no indication that rising CO₂ levels will stop at 700 ppm. Rather, it is quite possible that they will continue to rise to 4 times the pre-industrial level, or more than 1100 ppm, given current emission rates. For a quadrupling of CO₂, the estimated temperature increase for the U. S. would be 15 to 20° F, and soil moisture deficits could approach 30-50%. (Figures 13 and 14: 4xCO₂ surface air warming and soil moisture reduction)

Vulnerabilities and Potential Consequences

Although there is scientific uncertainty about exactly how, when, and where the Earth's climate will respond to increased concentrations of greenhouse gases in the future, observations clearly show that detectable changes are underway and that ecological systems are responding to these changes. These changes are adding important new stresses on ecological and socioeconomic systems that are already affected by pollution, increasing resource extraction, and non-sustainable management practices. Climatic changes that would result from a doubling of CO₂ would have pervasive effects, some of them irreversible, on ecological systems, human health, and socioeconomic sectors:

Health Effects - In general, developing countries are more vulnerable to climate change because of limited infrastructure and capital and greater dependence on natural resources. Children and the elderly are the most vulnerable population groups. Climate change will increase the risk of mortality from heat stress and from diseases that thrive in warmer climates, such as malaria, dengue and yellow fevers, encephalitis, and cholera.

- Mosquitos and other disease-carrying organisms are likely to expand their ranges northward, increasing the number of people exposed. The result could be, for example, 50-80 million additional malaria cases per year worldwide.
- Climate change can exacerbate air quality problems, such as smog, and increase levels of airborne pollen and spores that aggravate respiratory disease, asthma, and allergic disorders. (Figure 15: Smog photo)

Sea Level Rise - Sea level is expected to rise by 20 inches (50 cm) over the next century and by at least 80 inches (2 m) before equilibrium is reached several centuries in the future. Rising sea level erodes beaches and coastal wetlands, inundates low lying areas, and increases the vulnerability of coastal areas to flooding from storm surges and intense rainfall. A 20 inch sea level rise would double the population at risk from storm surges, from roughly 45 million at present to over 90 million world-wide. A 40 inch (1 m) rise would triple the number. In Florida, one-third of the Everglades would be lost with a 40 inch rise, and salt water intrusion would adversely affect delicate ecological communities and degrade the habitat for many species. (Figure 16: Florida shoreline with sea level rise) Even the 20 inch rise projected for the next century will result in substantial loss of coastal land in the U.S., where the Atlantic and Gulf Coasts are particularly vulnerable. Sea level rise in a "4 times" CO₂ world would be likely to exceed 80 inches (2 m), and could be substantially more depending on the extent to which the Greenland and Antarctic ice sheets melt.

Water Resources - Among the most fundamental effects of climate change is an intensification of the water cycle. This intensification will produce more severe droughts in some places and floods in others. Such events are costly. Damages from the southern plains drought of 1996 were estimated at \$4 billion and ranged from \$10 - \$20 billion for the

1993 Mississippi River flood. Areas of greatest vulnerability are those where quality and quantity of water are already problems, such as the arid and semi-arid regions of the U. S. and the world. (Figures 17: dry river bed picture)

- Climate change would likely increase stress in several US river basins, such as the Missouri, Arkansas, Texas Gulf, Rio Grande and Lower Colorado.
- Water scarcity in the Middle East and Africa is likely to be aggravated by climate change, increasing the risk of international conflict among countries such as Syria, Sudan, Egypt and Iraq, which depend on water supplies originating outside their borders

Forests - Climate change can dramatically alter the geographic distributions of vegetation types. The composition of one-third of the Earth's forests would undergo major changes as a result of a doubling of CO₂. Over the next century, the ideal range for some North American forest species will shift by as much as 300 miles to the north, far faster than the forests can migrate naturally. Economically important species, such as sugar maple, may be lost from New England. (Figure 18: sugar maple).

Other Natural Areas - Natural ecosystems, including those that make up our system of national parks and refuges - a \$ 3 billion annual investment - are highly vulnerable to degradation from climate change. The composition, geographic distribution, and productivity of many ecosystems will shift, leading to reductions in biological diversity and in the benefits they provide, such as clean water and recreation. Wetlands are particularly at risk. The wetlands of the prairie pothole region of North America, which support half the waterfowl population of this continent, could diminish in area and change dramatically in character in response to climate change. Mountain glaciers, which fluctuate rapidly in response to climatic change, will shrink. The glaciers of Glacier National Park have steadily for decades. By 1993, there had been a 73% reduction in the area of the Park covered by glaciers. (Figure 19: Glacier shrinkage in GNP)

Agriculture and Food Supply - Climate strongly affects crop yields. Doubling of CO₂ is likely to increase crop yields in some areas by as much as 30-40%, but decrease yields in other places by similar amounts, even for the same crop. A warmer, drier climate would reduce flexibility in crop distribution and increase irrigation demands. Expansions of the ranges of pests could also increase vulnerability and result in greater demand for, and use of, pesticides. Despite potentially large changes in yields, overall global food production is not expected to be altered substantially. Agricultural systems in the developed countries are highly adaptable and can probably cope with the expected range of climate changes without dramatic reductions in yields. It is the poorest countries, already subject to hunger, that are the most likely to suffer significant decreases in agricultural productivity. (Figure 20: Change in Grain Yield)

Fig 1 greenhouse effect

Fig. 2 Smokestack Photo

Fig. 3 Deforestation—Photo

Fig. 4 CO₂ concentrations 1860-present

Fig. 5 VP chart of CO₂ & temp over 160,000 y
→ only up to present

^{2nd} Fig. 6 1950-1990 vs. 2025
pie charts

Fig. 7 global Ave temperature 1860-present

Fig. 8 Photo of Floods

Fig. 9 Photo of permafrost melting

Fig. 10 VP chart including projections
of CO₂ & temp.

Fig. 11 Surface warming 2x CO₂

Fig. 12 % Soil moisture reduction 2x CO₂

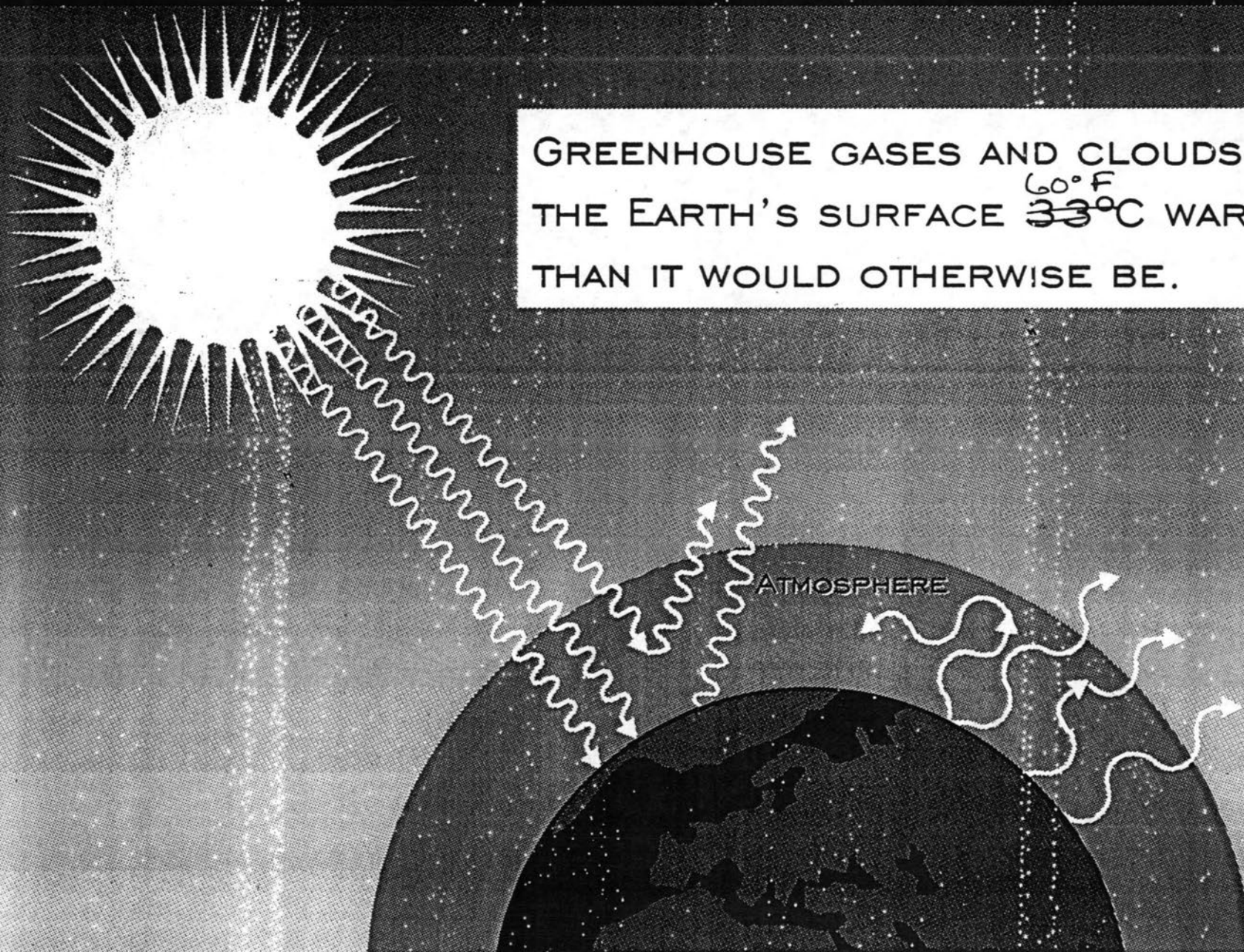
Fig. 13 Same as Fig. 11 4x CO₂

Fig. 14 " " Fig. 12 "

- Fig. 15 Photo of urban smog
- Fig. 16 South Florida shoreline
w/ sea level rise
- Fig. 17 Photo of dry river bed
- Fig. 18 Maps of Sugar Maple
under diff scenarios
- Fig. 19 Glacier Natl Park
- Fig. 20 Ag resources under doubled
CO₂

THE GREENHOUSE EFFECT

GREENHOUSE GASES AND CLOUDS KEEP
THE EARTH'S SURFACE ^{60°F}~~33°C~~ WARMER
THAN IT WOULD OTHERWISE BE.



Figures 2 & 3

are

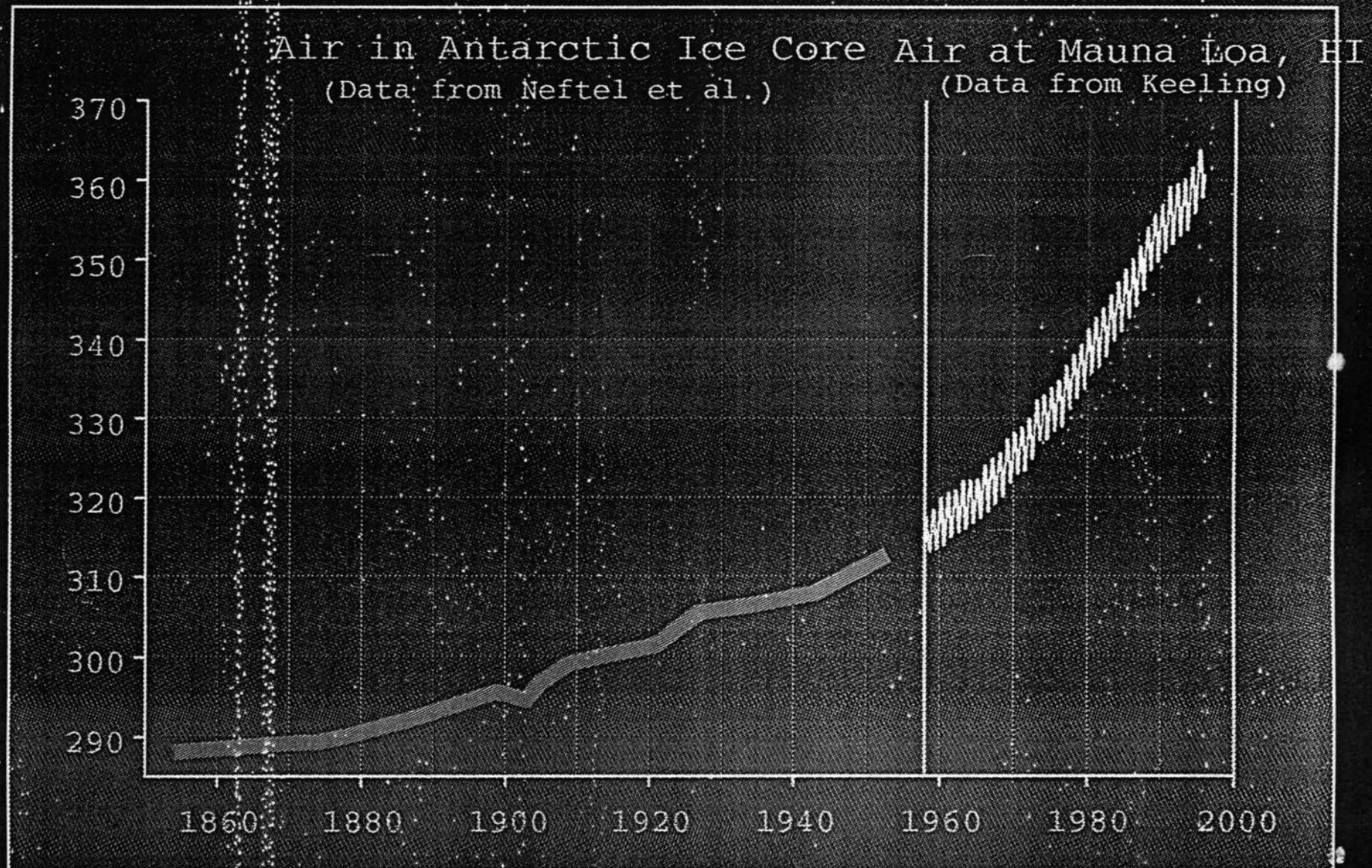
Photographs of

Smoke stacks (Fig. 2)

&

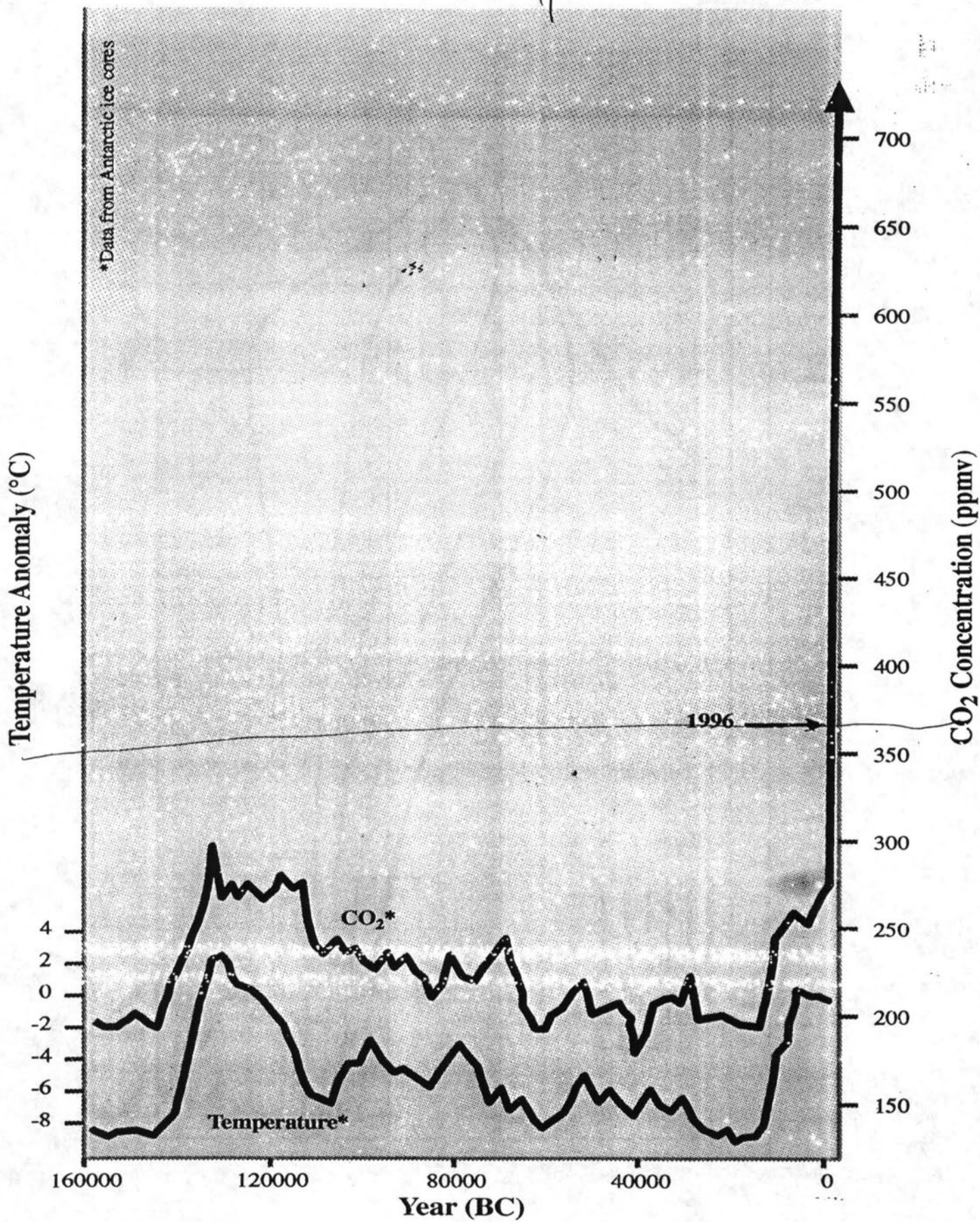
Deforestation (Fig. 3)

Carbon Dioxide Concentrations



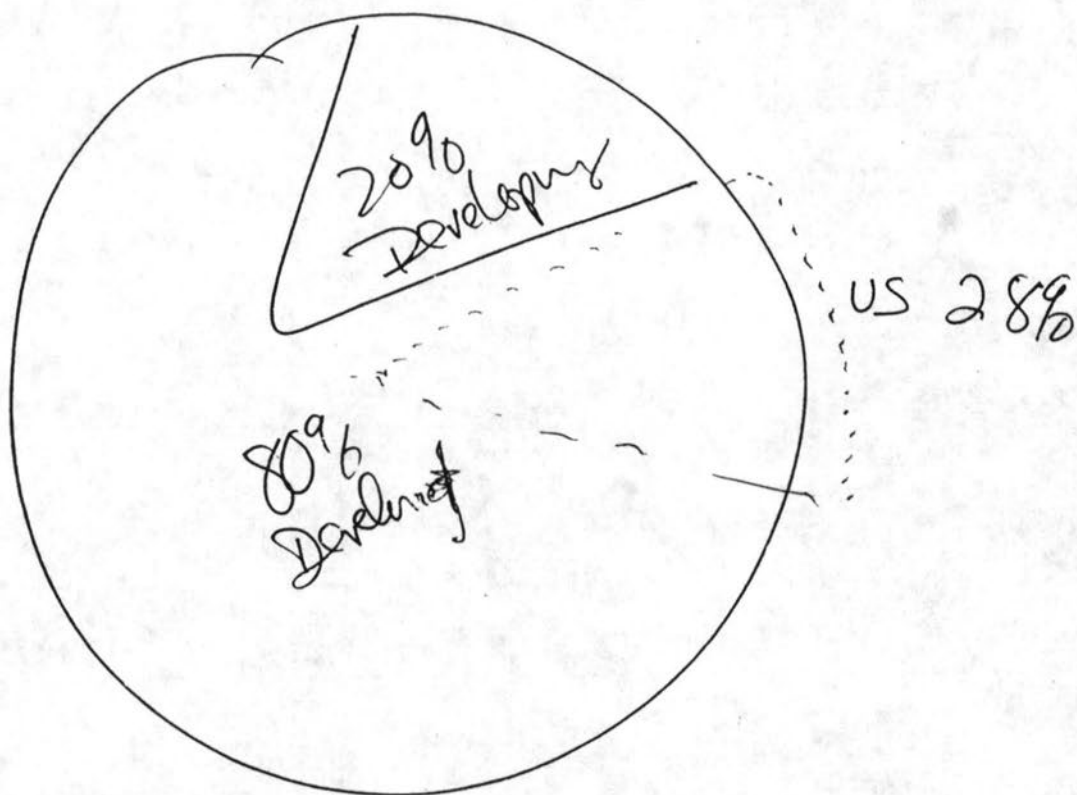
Up to present
only

5

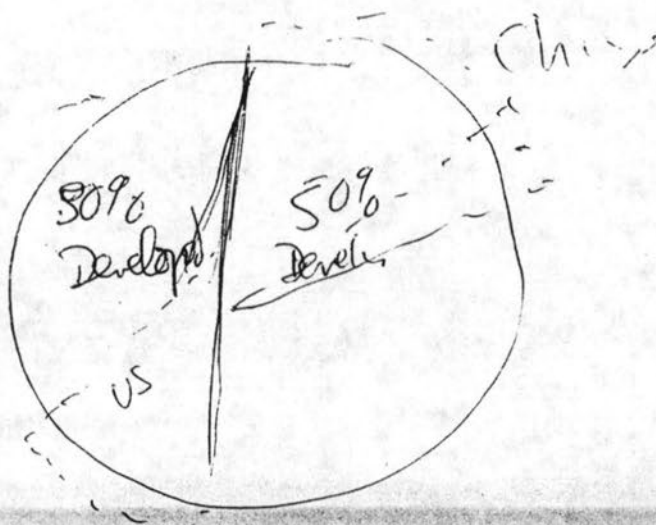


6

1950-1990



2035



Global Average Temperature

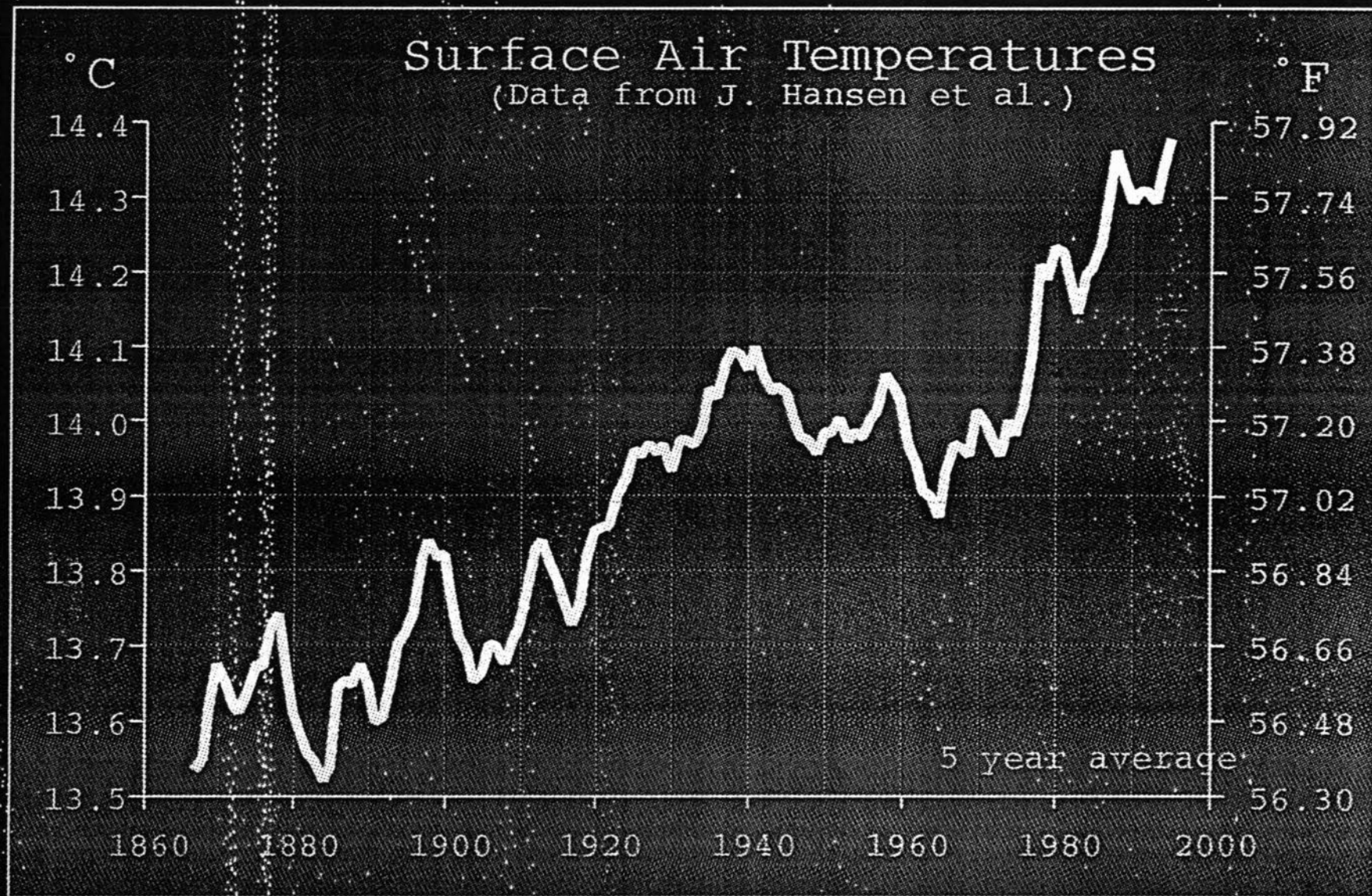


Figure 8

Photograph or image

of
flood

Figure 9

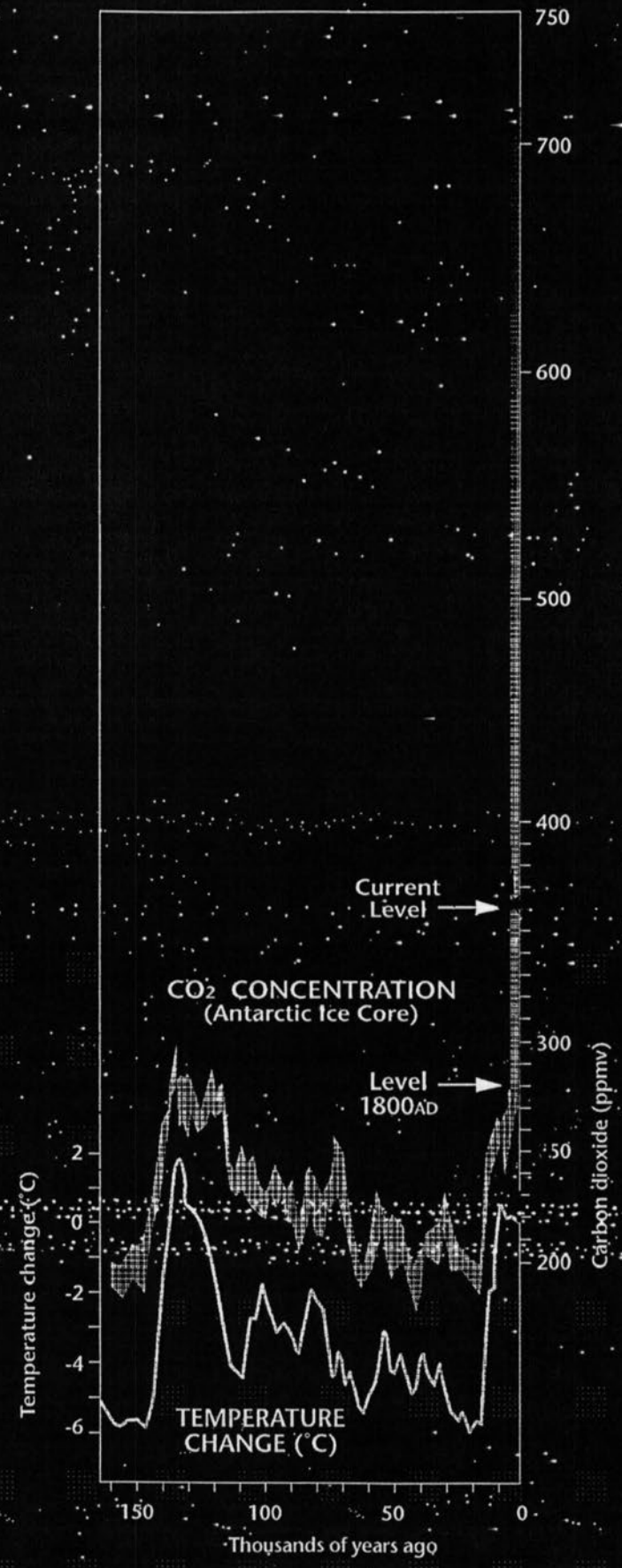
Photograph of

Permafrost melting

ie- Slumping road

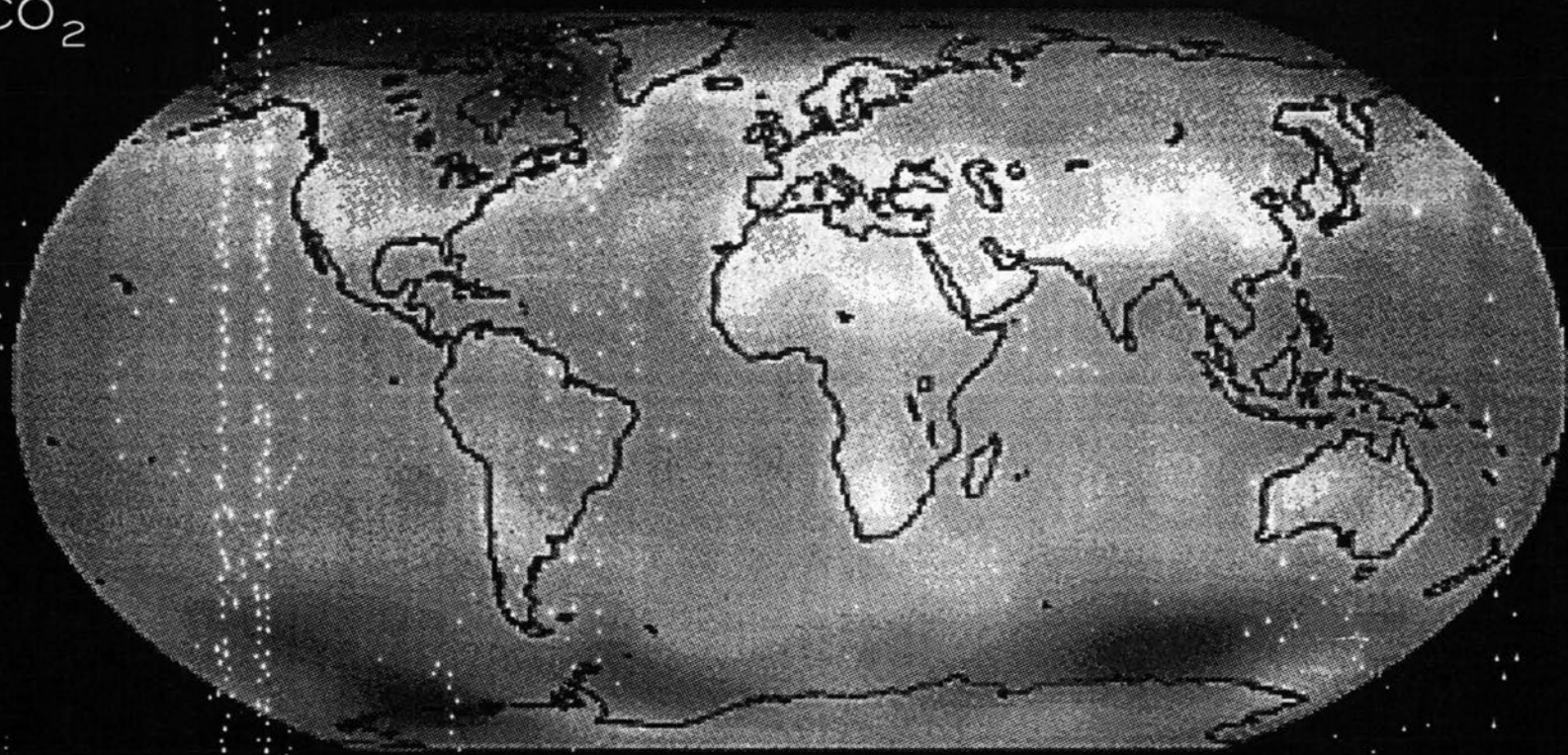
or forest slumping (ie- Ask Gunter Welter)

Atmospheric Carbon Dioxide Concentration and Temperature Change



SURFACE AIR WARMING (°F)

2xCO₂

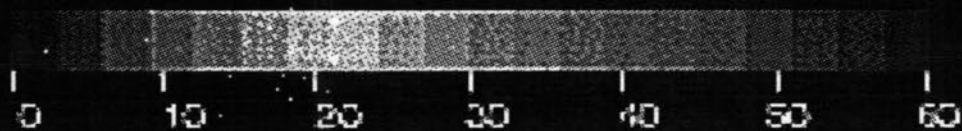
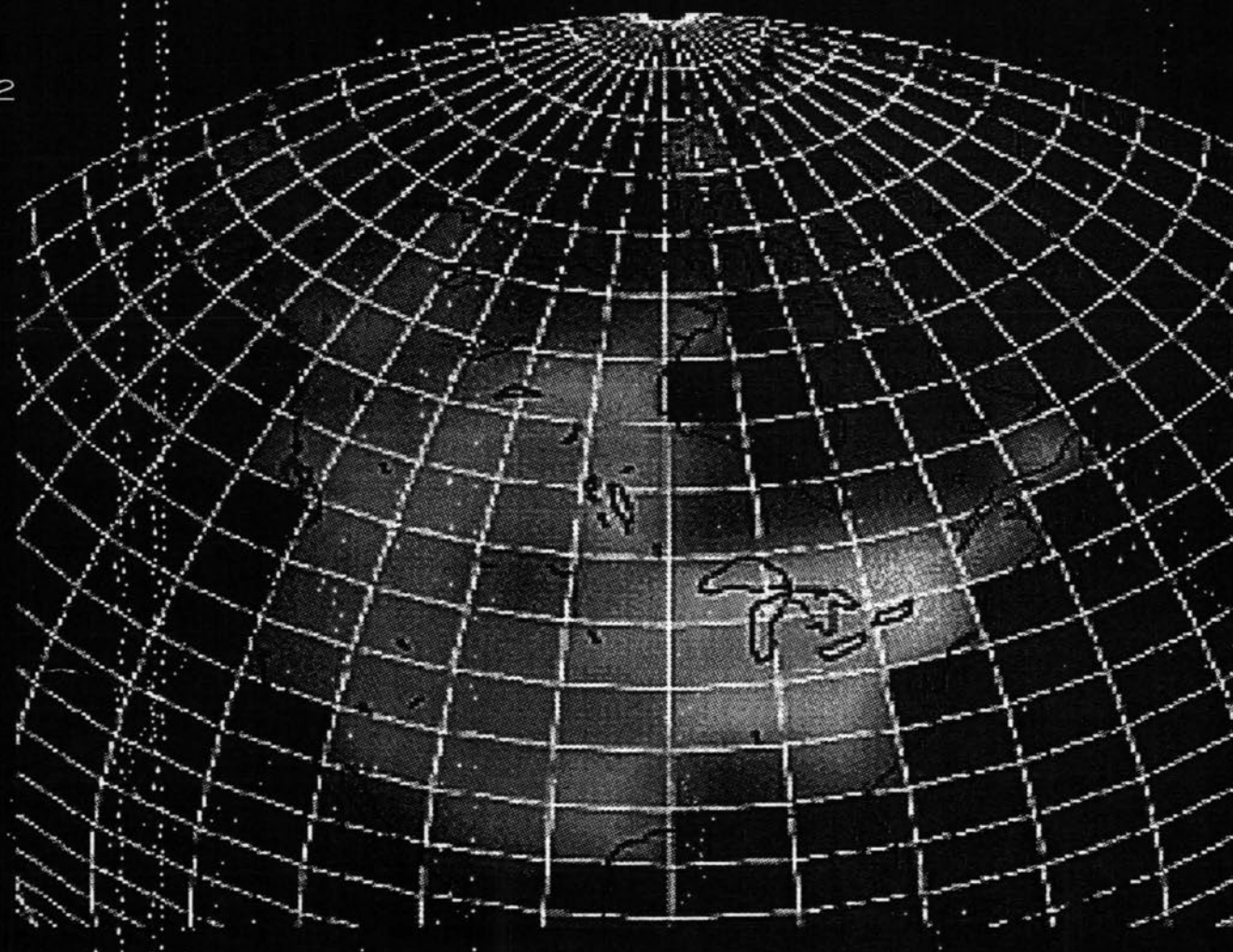


-5 0 5 10 15 20 25

SOURCE: GFDL R1.5 CLIMATE MODEL: CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

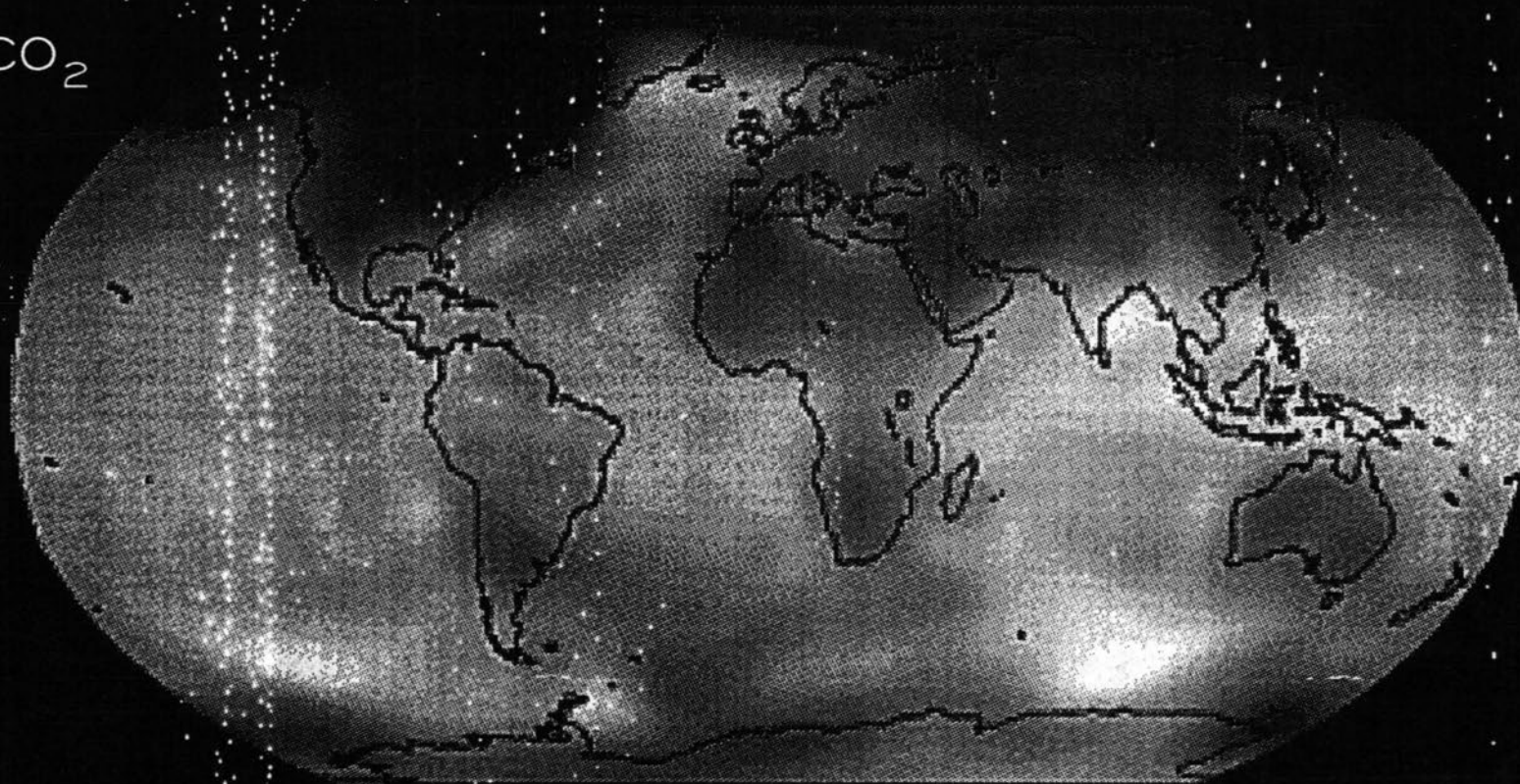
PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

2xCO₂



SURFACE AIR WARMING (°F)

4xCO₂



SOURCE: GFDL R1.5 CLIMATE MODEL: CO₂ TRANSIENT EXPERIMENTS, YEARS 401-500

PERCENT REDUCTION IN JUNE-AUGUST SOIL MOISTURE

4xCO₂

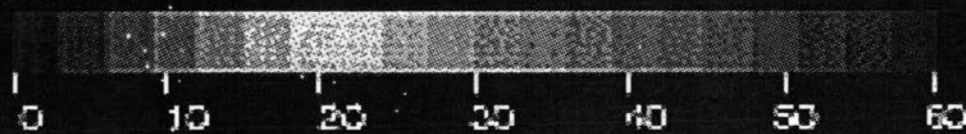
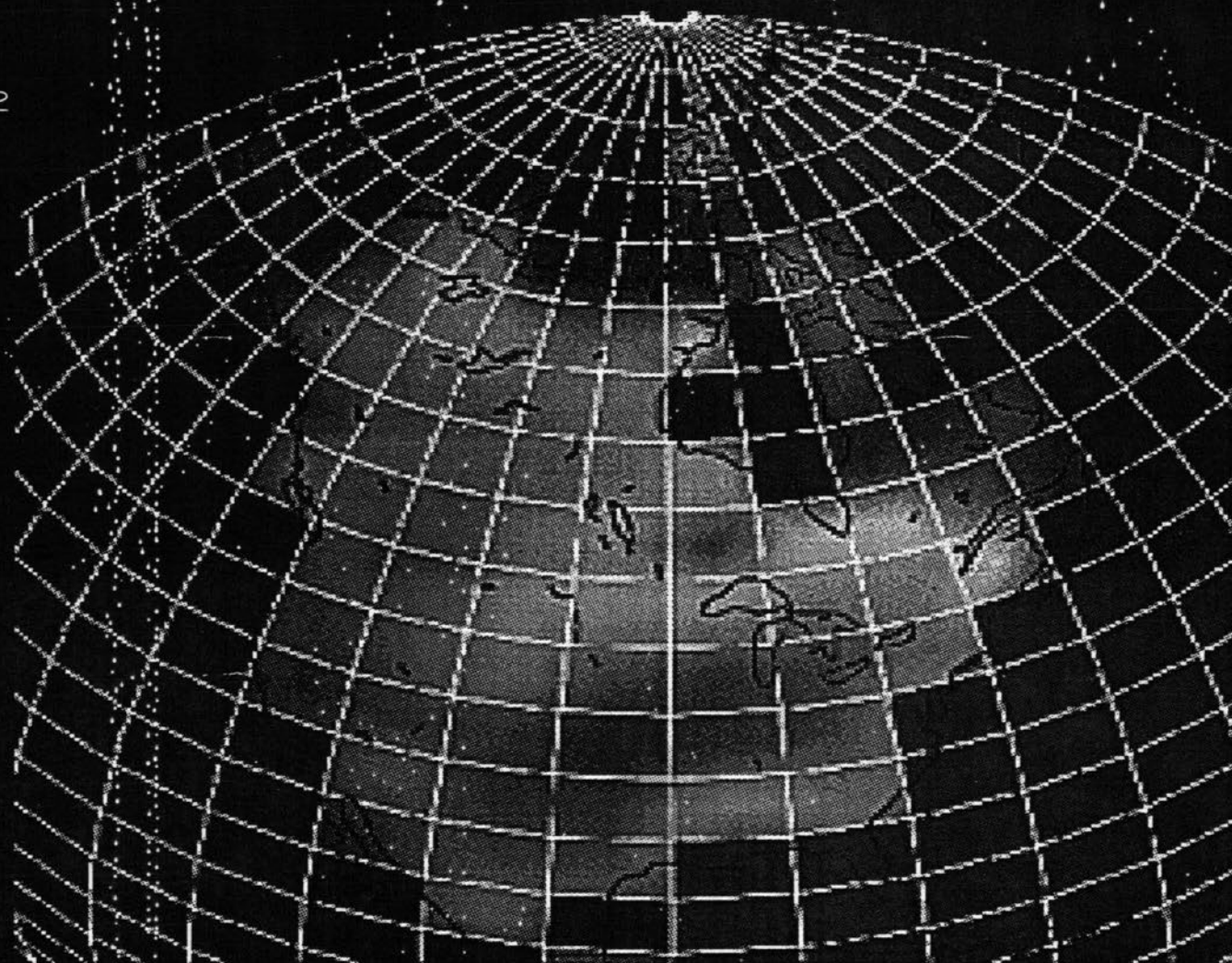


Figure 15

Photograph

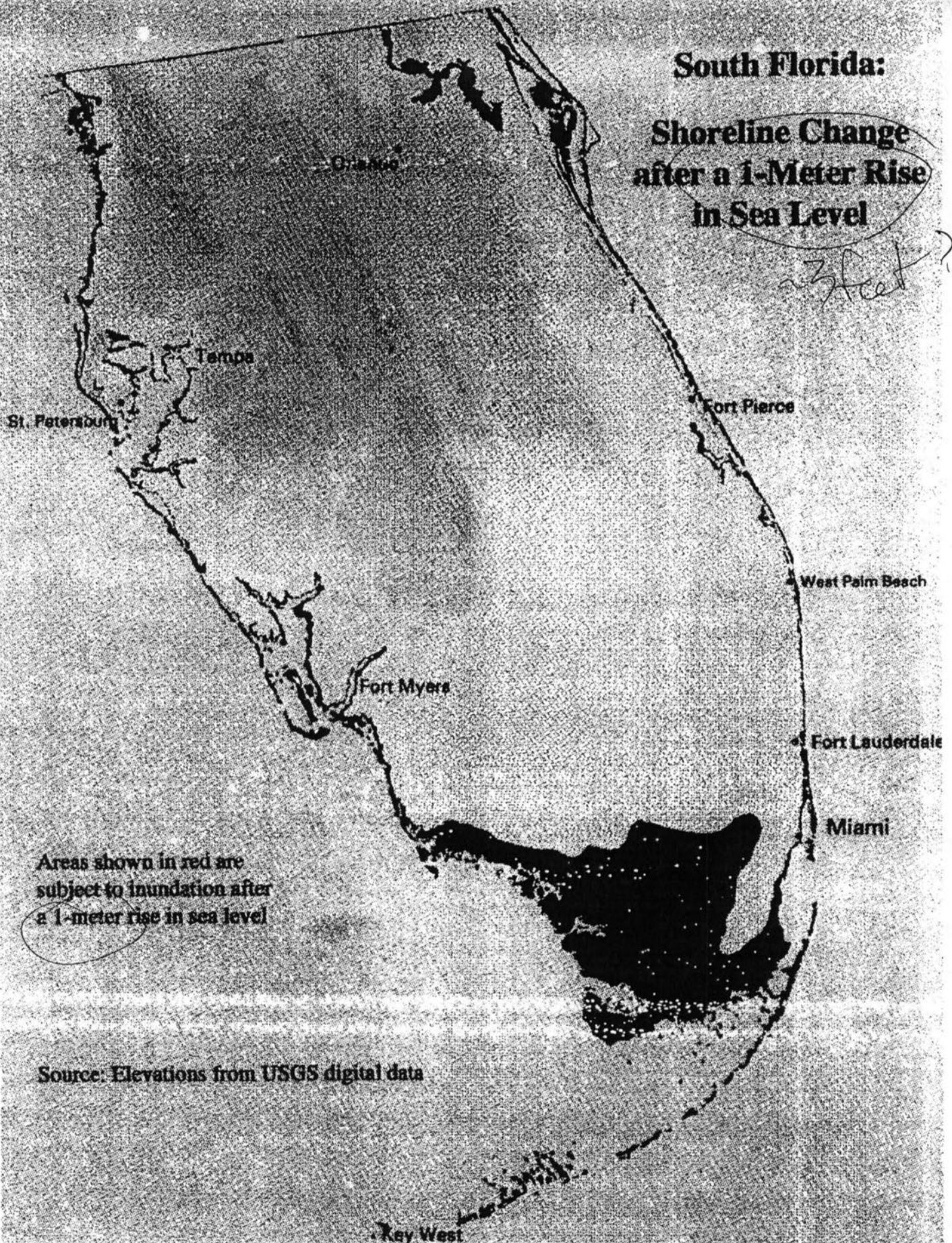
of urban smog

16

South Florida:

Shoreline Change after a 1-Meter Rise in Sea Level

~3 feet?



Source: Elevations from USGS digital data

Prepared by the U.S. Geological Survey, 1997

Fig. 17

Photo of dry

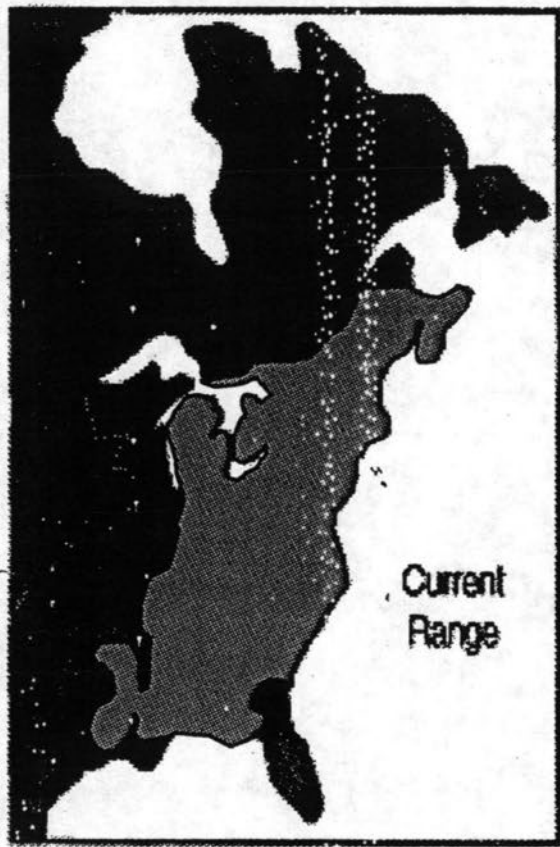
River bed

(V.Minn) Call Margaret Davis

use Sugar maple

18

CURRENT AND PROJECTED RANGES OF BEECH TREES IN THE U.S. UNDER TWO MODEL SCENARIOS



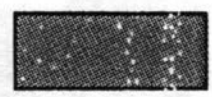
Current Range



GFDL Scenario



GISS Scenario



Current Growth



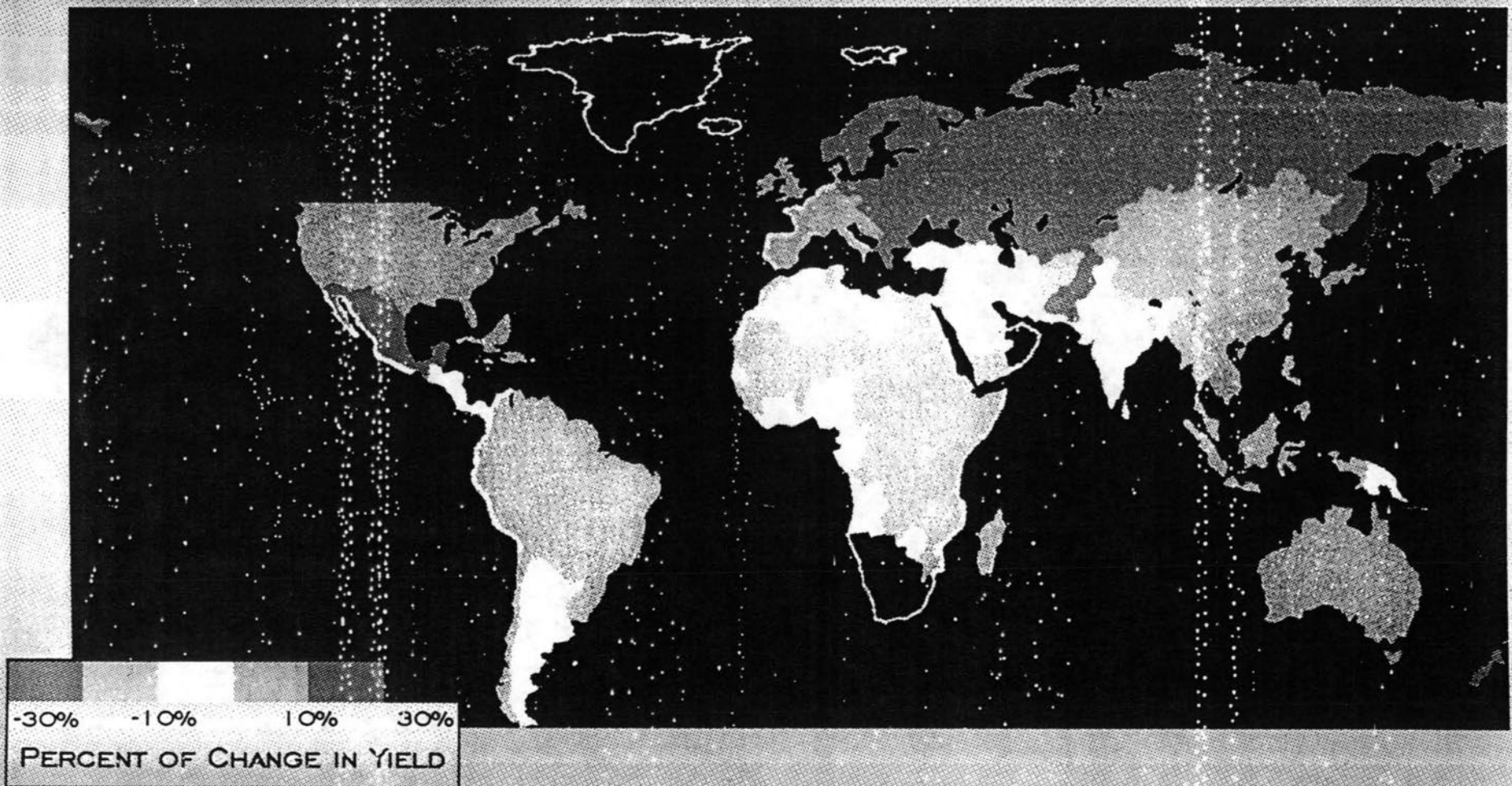
Projected New Growth

GLACIER SHRINKAGE IN GLACIER NATIONAL PARK

1850 - 1993



AGRICULTURAL RESOURCES: POTENTIAL CHANGE IN GRAIN YIELD DUE TO DOUBLED C_2



BASED ON GISS MODEL; PHYSIOLOGICAL CO_2 EFFECTS INCLUDED

SOURCE: ROSENZWEIG AND HILLEL (1993)