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LETTERS

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purpose. Our national interest dictates that "first things must come first." In establishing an order of priorities, many programs which we all wish to support simply must await the time when our fiscal and urban crises have been resolved. Though you may not agree with our particular ordering of priorities, we are sure you concur in the fundamental principle upon which the *Human Renewal Fund* is based. Accordingly, we earnestly ask that you request the President and the majority Leadership in the Congress to establish what they feel to be our national priorities. You have our fullest assurance that we will constructively support the President and the majority leadership if they will undertake such an effort. . . .

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GEORGE BUSH, M.C.
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ALBERT H. QUIE, M.C.
HOWARD W. ROBINSON, M.C.
DONALD RUMSFELD, M.C.
WILLIAM A. STEIGER, M.C.
House of Representatives
Washington, D.C.

LETTERS

AN OPEN RESPONSE

As eight Republican members of the United States House of Representatives—who advocate deferral of \$6.6 billion in low priority federal spending and plow back of \$2.5 billion of the savings into high priority programs meeting urgent human and urban needs—we welcome your "Open Letter" [SR, 15 Apr '68, 7] which constructively criticizes one aspect of our proposal—*The Human Renewal Fund*. We appreciate this opportunity to present an "Open Response" to your criticism—that expenditure of \$250 million in National Science Foundation funds should not be deferred during our nation's present fiscal and urban crises.

We believe the magnitude of these crises, fiscal and urban, require that our national priorities be reordered. All Americans—rich and poor, young and old—sensitively feel the pressure of the dollar's declining value and vividly view the havoc wrought in city ghettos. It is our belief—which you doubtless share—that this country deserves leadership which will make the necessary hard and tough decisions to resolve the fiscal crisis, while not neglecting the considerable needs of America's underprivileged and poverty stricken. To accomplish both objectives requires a careful and balanced approach, which tightens our "fiscal belt," but which still commits a meaningful appropriation to essential urban and human programs. The national interest demands such a solution.

Our proposed solution, intended as a constructive recommendation to solve these crises, was made without the assistance of the President's immense resources, e.g. the Bureau of the Budget, and the full consideration of Congressional Committee hearings. Unfortunately, these resources are not at our disposal. We acted, nevertheless, as a small group of men, determined and convinced that something must be done. Our recommendations were intended to show that what must be done can be done. National priorities can be re-ordered.

Each of us who proposed these deferrals is firmly committed to the Federal Government's basic research efforts, which total nearly \$17 billion. At the same time, however, we are committed to putting the nation's "fiscal house" in order and to meeting the needs of the underprivileged and poverty stricken. You may be interested to know that the deferrals in the *Human Renewal Fund* affect less than 1½ percent of the Federal Government's total basic research efforts.

Practically every spending deferral recommended in the *Human Renewal Fund*, including the National Science Foundation, touches upon sensitive programs of importance to particular interest groups. Politically, each of our own Congressional Districts is vitally affected by certain of these recommendations. In short, the *Human Renewal Fund* is not a popular political undertaking solely designed to win votes; rather, its expressed purpose is to seek the national interest at a critical juncture in our history.

Our nation can no longer continue to commit her resources without a sense of priority and

(continued on page 40)

Pseudo-Scientific Hot Air

Ch

By Andrew R. Solow

Good science is often boring. Good science fiction is usually exciting. This may explain why recent stories about the greenhouse effect have been so exciting.

The typical story — usually told by a scientist in Congressional testimony — goes something like this: Global temperature depends on atmospheric composition, which is affected by human activities like burning fossil fuels. Consequently, these activities may cause atmospheric warming. This, in a nutshell, is the greenhouse effect.

The scientist mumbles something about being uncertain of the actual timing, effects and magnitude of the greenhouse effect. Then the fun begins. Disclaimers aside, the scientist goes on to describe a future of stifling heat, waves, unrelenting drought and rising seas.

The testimony is featured in the next day's papers. The scientist appears on the morning news programs. Magazines print alarming stories replete with lurid graphics. Calls for drastic action ring out.

Meanwhile, those of us who are also concerned about climate change but who recognize the enormous uncertainties and are doing the difficult and (I like to think) important work of reducing these uncertainties, wistfully contemplate early retirement.

What can we really say about future climate? There are three ways of making climate predictions. The first is through theory.

Theory says that increasing the atmospheric concentration of carbon dioxide may lead to warming. Because the concentration of carbon

dioxide is increasing, we worry about warming. Beyond that, we do not know enough about climate processes to make useful predictions from theory alone.

The second way of making climate predictions is through computer models. These models are large systems of equations representing our understanding of climate processes. Because our understanding is limited, the models are of limited use. For example, these models have a hard time reproducing current climate from current data. They cannot be expected to predict future climate with any precision.

The third way of making climate predictions is by using existing data. Although this is the crudest way — the past being a potentially poor

dicted under the greenhouse effect.

The current warming started before the greenhouse effect could have begun. If the greenhouse effect had begun during the course of the data, then we would see the warming accelerate. No acceleration appears in the data. The current warming is consistent with a mild post-glacial period, probably the aftermath of the so-called "little ice age" that ended during the 19th century.

The conclusion is that we cannot yet make useful predictions about climate, and that existing data show no evidence of the greenhouse effect. Many people will be surprised to hear that this is more or less the view expressed in scientific journals, where articles are subject to peer review. Unsubstantiated or misleading statements only appear in such journals when the review process fails. Congressional testimony and interviews in the press are not subject to peer review, and that is how unsubstantiated and misleading statements come to dominate public discussion.

Some will say that the scientific establishment demands an unreasonable degree of certainty before accepting a new idea. But in the case of climate change, and particularly with regard to detecting change with existing data, it is not a question of the evidence being tenuous. It is a question of there being no evidence at all.

And some will say that if we wait until we're sure about climate change, then it will be too late to do anything about it. Of course, this argument applies equally to an invasion by aliens from space. More seriously, this argument neglects the costs of overreaction.

Take the consumption of fossil fuels. Like it or not, this contributes to our standard of living. Policies that curtail such activities will reduce our standard of living. For this reason, such policies need better justification than current fears about climate change.

By Ren War

It has been 10 years since the "democracy wall spring" came into the world. In this decade, grass has taken place elsewhere. Détente has become irreversible.

Linked to the "Beijing Spring" were numerous groups, including art and music nongovernmental public sprang up like bamboo in the country. They lasted when they were banned in larger sense the "Beijing Spring" continues to show its signs to guide the reform process.

China's political situation and 1979 forced its people to live under political and material poverty for decades, again to clamor for democracy and human rights.

It was the democracy wall suggested the "open-door" China. It was the first to crisis in China as the rest leaves it behind. The "spring" pointed out the lifelong terms of office for leaders. Some of our ideas, unrealistic, are being implemented.

Since the first cries arose for human rights and social justice, those who protested have been censored and charged with large number of talented people thrown in jail. Even their terms of punishment continue to be discriminatory in their jobs and living conditions.

The nationwide student demonstrations at the end of 1986 were

Ren Wanding, a leader of the democracy wall movement, was imprisoned from 1979 to 1983.

The data on climate are inconclusive.

guide to the future — existing data can, for example, tell us if the greenhouse effect has already begun. Temperature data for the last 120 years show an irregular warming of about 1 degree Fahrenheit over the past century. Over some periods, this warming was relatively rapid. The 1980's has been such a period, as were the 1890's and 1920's.

Because the greenhouse effect is associated with warming, and the data show warming, can we conclude that the greenhouse effect has begun? Not unless we are prepared to believe that the only cause of warming is the greenhouse effect. There are indications that the current warming is unrelated to the greenhouse effect. The rate of warming is far below that pre-

OBSERVER | Russell Baker

Getting Tired of High-Culture

I have long intended to become as knowledgeable about the arts as that critic who reviews them for wise-guy weekly publications issued from New York.

Surely you have read his reviews. If he goes to a Rembrandt exhibition, he spends most of the review talking about Rembrandt's technique.

early works of the Clambake Trio.

This reviewer is familiar with every painting ever painted, every writer who ever wrote, every theatrical enterprise ever enterprised, every musical note ever played.

I do not doubt that he is. Experience has proved that some people indeed

lap it up in vast quantities would be more modest about flaunting the stuff in their mental attics.

I suspect the reviewer cited above is less interested in telling me the cultural news than in reminding me that I don't know Vlaminck from Minsky; that I still haven't gotten around to

How I prepared for a movie review

Table I. Summary of important trace gases with growing surface emissions.

Gas	Common name	*Surface concentrations	*Atmospheric trend	Atmospheric lifetime	Primary man-made sources
CO ₂	Carbon dioxide	345 ppmv	~0.4% /yr	~500 yrs (air-biosphere-oceans)	fossil fuels burning; land use conversion.
CH ₄	Methane	1.7	~1	~7-10	domestic animals; rice paddies; biomass burning; gas and mining leaks.
CO	Carbon monoxide	0.12	~1-2	~0.4	energy use; agriculture; forest clearing.
N ₂ O	Nitrous oxide	0.31	~0.3	~150	fossil fuel burning; cultivation and fertilization of soils.
NO _x (=NO + NO ₂)	Reactive Odd	1-20 × 10 ⁻⁶	unknown	≤0.02	fossil fuel burning; biomass burning
CFCl ₃	CFC-11	2.0 × 10 ⁻⁶	~5	~75	chemical industry produced.
CF ₂ Cl ₂	CFC-12	3.2 × 10 ⁻⁴	~5	~110	chemical industry produced.
C ₂ Cl ₃ F ₃	CFC-113	3.2 × 10 ⁻⁶	~10	~90	chemical industry produced.
CH ₃ CCl ₃	Methyl chloroform	1.2 × 10 ⁻⁴	~5	~6-9	chemical industry produced.
CF ₂ ClBr	Ha-1211	1 × 10 ⁻⁶	~10-30	~12-15	fire extinguishers.
CF ₃ Br	Ha-1301	1 × 10 ⁻⁶	unknown	~110	fire extinguishers.
SO ₂	Sulfur dioxide	1-20 × 10 ⁻⁶	unknown	~0.02	coal and petroleum burning.
COS	Carbonyl sulfide	5 × 10 ⁻⁴	<3	2-2.5	biomass burning; fossil fuel burning

* Corresponds to mid-1980s values.

The Importance of Tropospheric OH

The hydroxyl radical, OH, is not itself a greenhouse gas with a direct radiative effect on climate, but it is extremely important as a chemical scavenger of many trace gases in the troposphere. OH is the primary tropospheric scavenger of CH₄, CO, CH₃CCl₃, CH₃Cl, CH₃Br, H₂S, SO₂, DMS (di-methyl sulfide), and other hydrocarbons and hydrogen-containing halocarbons. Some of these species, such as CH₄, do have direct radiative effects on climate. Therefore, a change in global OH concentrations can impact the atmospheric lifetimes of these species, and thereby modify abundances and climate. Reactions with OH in the troposphere also limit the amount of CH₄ and halocarbons reaching the stratosphere, where these species can lead to changes in the ozone

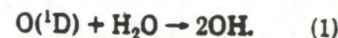
distribution. In addition, OH and other closely related species in the HO_x family play a central role in production of tropospheric ozone by oxidizing NO to NO₂, by removing active forms of NO_x, and in the lower troposphere, by initiating the oxidation of hydrocarbons.

Table II indicates, for the same gases described previously in Table I, that OH is closely coupled, both in its formation and destruction, with gases important to the atmospheric climate-chemical system. We will describe the sources and sinks of OH, and then consider the relationships between climate change and its atmospheric concentrations.

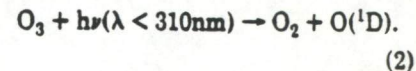
Sources and Sinks of OH

The major source for OH and reactive odd-hydrogen HO_x (OH, HO₂,

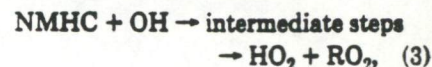
H₂O₂, HNO₃, etc.) in the background global troposphere is the reaction of excited oxygen atom, O(¹D), with H₂O:



The O(¹D) is generated by photolysis of ozone near 300 nm:



In regions of high NMHC (non-methane hydrocarbons), the oxidation of these species can add to the HO_x family by radical chain reactions:



which lead to OH production after reactions with NO or O₃ that convert HO₂ and RO₂ to OH.

Key sinks for hydroxyl, though not

Table II. Direct radiative effects and indirect trace gas interactions affecting climate.

Gas	Greenhouse gas?	Are its tropospheric concentrations affected by chemistry?	Indirect effects on . . . Tropospheric chemistry?	Stratospheric chemistry?
CO ₂	yes	no	no	yes, affects O ₃
CH ₄	yes	yes, reacts with OH	yes, affects OH and O ₃	yes, affects O ₃ , H ₂ O
CO	no	yes, reacts with OH	yes, affects OH and O ₃	not significantly
N ₂ O	yes	no	no	yes, affects O ₃
NO _x	no	yes, reacts with OH, O ₃	yes, affects OH and O ₃	yes, affects O ₃
CFCl ₃	yes	no	no	yes, affects O ₃
CF ₂ Cl ₂	yes	no	no	yes, affects O ₃
C ₂ Cl ₃ F ₃	yes	no	no	yes, affects O ₃
CH ₃ CCl ₃	yes	yes, reacts with OH	no	yes, affects O ₃
CF ₂ ClBr	?	yes, photolysis	no	yes, affects O ₃
CF ₃ Br	yes	no	no	yes, affects O ₃
SO ₂	yes, but weak	yes, reacts with OH	yes, but not significant to climate	yes, increases aerosols
COS	yes, but weak	yes, reacts with OH	no	yes, increases aerosols

Clean Air? Don't Hold Your Breath

Over the next few months, Congress will try to rewrite the Clean Air Act. Economists argue that existing smog standards are already too costly, while researchers raise new health concerns.

PERHAPS LOS ANGELENOS will give up their patio torches, stop driving solo on the freeway, quit buying underarm sprays that use petrochemicals, build no more drive-through banks or restaurants, renounce charcoal lighter fluid, even surrender the backyard charcoal grill. Perhaps.

These and other graces of Southern California life are endangered by a radical new proposal to clean up the city's air. A regional board last month actually adopted a plan that would require inhabitants of Los Angeles to change their ways, stirring hope among environmentalists of achieving some long-neglected goals of the Clean Air Act—a law that has been violated since its enactment in 1970.

Los Angeles, which has the nation's dirtiest air, is the law's worst violator. But it is not the only one. Most big cities cannot meet the federal limit on ozone, the key ingredient in smog. By one estimate, about 20 cities would have to undergo a wrenching overhaul like the one proposed for Los Angeles if they were to try to meet the law in 5 years. The reality is that urban America is not remotely within reach of the standards in the Clean Air Act.

This stark fact, some economists say, calls not for a drastic revision of life-styles, but for a revision of the law. The law should be rewritten, they argue, to allow the Environmental Protection Agency (EPA) to weigh the costs and benefits of controlling pollutants like ozone and to defer action when meeting the health standard is not urgent. Right now, the law provides no such flexibility.

Just the opposite message comes from EPA's animal research labs in North Carolina and from specialists on lung disease at academic medical centers around the country. The most recent data, collected by Donald Horstman, Lawrence Folinsbee, and William McDonnell in EPA's large air chamber on the Chapel Hill campus of the



Los Angeles smog. A cleanup plan for the city, hailed by some as a model for the rest of the nation, could cost \$12 billion a year by 2000 and force Los Angelenos to change their life-styles.

University of North Carolina, show that the biological effects of ozone can be detected in humans at lower concentrations than ever seen before, well below the federal "enforcement" standard of 0.12 part per million (ppm). And James Crapo at Duke University, using a sophisticated new kind of pathology, found evidence of inflammation and fibrosis in rat lungs after the animals had lived for 18 months in an air-ozone mixture like the summer breezes of Los Angeles.

Most health researchers decline to say what policy implications they see in these findings. Indeed, a scientific advisory committee to EPA could not reach agreement recently on whether to recommend that the existing ozone standards should be toughened in light of the new evidence.

The economists likewise skitter away from the science. At times, the two professional groups seem to talk right past one another, making it hard for lay persons like those

who govern the country to know what to make of all the information.

Like it or not, the Bush Administration and Congress will become expert in these technical subtleties over the next few months, for they are facing a deadline on renewal of the Clean Air Act, an action that has already been delayed 2 years (see box on page 518).

On one point, at least, all sides seem to agree: the air in Los Angeles—where ozone sometimes hits triple the federal limit—is so bad that a cleanup should begin immediately. Washington will be watching what happens in Southern California closely.

A jab from environmentalists in the form of a lawsuit started the region moving toward cleaner air this spring. On 17 March, California's South Coast Air Quality Management District voted overwhelmingly to adopt a new attack on ozone, a highly reactive form of oxygen.

Paints, glues, and pesticides would be reformulated to reduce volatile hydrocarbons. Buses and cars would be electrified. New transit systems would be built. Fleets of methanol- and ethanol-fueled autos would be deployed. (These fuels contain more oxygen than gasoline and burn more completely.) Major new controls would be imposed on all kinds of public and private activities, at the rate of 30 to 40 significant measures per year for the next 20 years, according to a regional EPA official. This seems to be the only way to achieve the 70 to 80% decrease in emissions that will be needed to meet U.S. pollution standards.

The Los Angeles plan has been hailed as a guide to the rest of the nation, as the *New York Times* editorialized, "a model and an inspiration to Washington." But there are some tough questions about its feasibility, about the commitment of local governments to carry it out, and about its cost.

Paul Portney, an economist at Resources

The "brute force method" of control may exacerbate the problem.

—Milton Russell

for the Future, a Washington, D.C., think tank, made this point at a recent meeting in Boston attended by health researchers. The Los Angeles plan is structured in three tiers, only the first of which has been costed out, in part. This tier would take the city one-third of the way toward compliance with the ozone standard. Portney told the Boston crowd that it would cost about \$4 billion per year, and that each successive tier would be more radical and perhaps more expensive than the one before. By 2000, it would cost Californians \$12 billion a year. "Think of what you can get for \$12 billion," Portney says. He suggests the money might be put into other pro-health accounts such as food stamps (1989 national cost: \$12.8 billion), infant food supplements (\$1.9 billion), child nutrition programs (\$4.6 billion), or community health centers (\$400 million). When Portney said this in Boston, "People went bonkers," he recalls.

Milton Russell, another economist, quotes Office of Technology Assessment numbers suggesting that it could cost the nation \$10 billion to \$20 billion per year to put into force a modest plan to meet existing standards. This is more than the acid rain control bills in Congress are expected to cost. Tightening the ozone standard, as some members of EPA's Clean Air Scientific Advisory Committee are recommending, would raise the cost further.

Russell, who headed EPA's policy office in the mid-1980s and now works at the

University of Tennessee and Oak Ridge National Laboratory, wrote in a report last fall that the "brute-force" method of lowering ozone precursor emissions across the nation "may exacerbate rather than improve the problem." If local officials see no clear advantage in complying with the law and balk, it could "set the government on a course of failure," leading to scorn for environmental controls in general. He pleads for realism, or at least some relaxation of the rigid health standards of the Clean Air Act.

According to law, the ozone concentration should not exceed 0.12 ppm, averaged over 1 hour, on more than 3 days in 3 years. This standard, set in 1979, is based on research done in the 1970s that reported ozone effects in humans at 0.15 ppm. The official limit was set a smidgen lower for the "margin of safety" required by law. A duration of 1 hour was chosen because it seemed the best way to focus attention on acute exposure of the kind in Los Angeles, where the ozone concentration quickly reaches high peaks in the rush hour, then drops.

The effects of low ozone doses were established by watching athletes perform in a smoggy atmosphere at the University of California at Davis in the 1970s. Those early measurements have been confirmed and strengthened by air chamber studies. Until recently, the procedure usually called for a volunteer—often a young athlete—to exercise near the top of capacity in an air and ozone mixture for an hour. (Later studies use less ozone and run longer, with plans now for a marathon 8-hour test.) Afterward, the subject blows into a tube attached to a meter. The consistent result: the volunteer cannot take as deep a breath after the ozone dose as before. If the exposure is repeated a second day, the effect increases.

There is a distinct group of people who are particularly sensitive to ozone, as recent research shows, not necessarily the same ones who suffer from asthma, allergies, or other lung diseases. Some asthmatic are affected strongly by ozone; others are not. The evidence from the lab does not seem to link ozone to any particular disease, although some epidemiological studies indicate that asthmatics are admitted to hospitals more frequently during heavy pollution.

The sensitive people show marked symptoms after a moderate dose of ozone—burning in the chest, coughing, wheezing, and sometimes sharp pain. Their loss of deep breathing capacity, or "lung function," can be 25% or so. The more common response to low doses of ozone among non-sensitive people is a lung capacity loss of less than 10%.

If the ozone exposure is continued through 4 or 5 days, a puzzling thing hap-

pens. The lungs seem to toughen or adapt, and breathing returns to normal. Lab animals follow much the same pattern. Weeks later, if the volunteer has been kept off ozone and is re-exposed, the cycle goes back to day one, revealing a loss of lung function again.

This effect is easiest to detect in healthy, heavily exercising young people. Cigarette smokers, for example, do not seem to be affected. Nor do older people exhibit a striking response, perhaps because their lungs are stiffer, a result of aging.

To some, this suggests that the lungs of the youthful ozone initiate are just being toughened up to meet the real challenges of life, in the way muscle fibers are torn during exercise, leading to greater strength.

Kenneth Gross, a physiologist in General Motors' biomedical research department, says: "Change doesn't necessarily mean there is an adverse health effect. If you consider change to be adverse, then living is adverse to your health." He continues: "A small change in lung function that can't be perceived by the person and is reversible in a couple of hours—I'm not sure what that means for public health."

But other data, particularly studies of animal lungs, support a different view. The short-term loss, although reversible, may be part of a pattern that leads to stiffer, less efficient lungs earlier in life. Bernard Goldstein, former chief of research at EPA, now at Rutgers University, says it may be analogous to "scratching yourself in the same place over and over again; you're going to



"We haven't got the foggiest idea how to meet the existing standard."

—Bernard Goldstein

self-cleansing ability of the atmosphere by lowering the concentration of the hydroxyl radical, which is an important "detergent" because it reacts with nearly every trace-gas molecule in the atmosphere, including substances that would otherwise be inert. Without hydroxyl, the concentrations of most trace gases would become much higher than those of today, and the atmosphere as a whole would have totally different chemical, physical and climatic properties.

Our projections for the future are discouraging, then, if one assumes that human activities will continue to emit large quantities of undesirable trace gases into the atmosphere. Humanity's unremitting growth and development not only are changing the chemistry of the atmosphere but also are driving the earth rapidly toward a climatic warming of

unprecedented magnitude. This climatic change, in combination with increased concentrations of various gases, constitutes a potentially hazardous experiment in which everyone on the earth is taking part.

What is particularly troubling is the possibility of unwelcome surprises, as human activities continue to tax an atmosphere whose inner workings and interactions with organisms and nonliving materials are incompletely understood. The Antarctic ozone hole is a particularly ominous example of the surprises that may be lurking ahead. Its unexpected severity has demonstrated beyond doubt that the atmosphere can be exquisitely sensitive to what seem to be small chemical perturbations and that the manifestations of such perturbations can arise much faster than even the most astute scientists could expect.

Nevertheless, some steps can be tak-

en to counteract rapid atmospheric change, perhaps lessening the known and unknown threats. For example, evidence indicates that a major increase in the rate of fossil-fuel combustion would slow the greenhouse warming, reduce smog, improve visibility and minimize acid deposition. Other steps could be targeted against particular gases, such as methane. Methane emission could be reduced by instituting landfill operations that prevent release and possibly by adopting less wasteful methods of fossil-fuel production. Methane emission from cattle might even be diminished by novel feeding procedures.

Perhaps more encouraging is the fact that many people and institutions are now aware that their actions can have not only local but also global consequences for the atmosphere and the habitability of the planet. A few recent events exemplify this aware-



PHOTOCHEMICAL SMOG, here shrouding São Paulo, Brazil, is a problem in many urban areas. It forms when solar radiation acts on emissions—notably nitrogen oxides and hydrocarbons

from vehicle exhaust—to produce an undesirable mixture of gases near the ground. The major component is ozone (O_3), which can harm the eyes and lungs and damage trees and crops.

GLOBAL MARINE TEMPERATURE VARIATION AND THE SOLAR MAGNETIC CYCLE

Nicholas E. Newell

Arlington, Mass.

Reginald E. Newell, Jane Hsiung and Wu Zhongxiang

Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology

Abstract. Global and hemispheric marine temperatures for 1856-1986 have been subjected to harmonic analysis. We investigated a prominent 22-year peak in the Fourier Transform by subtracting from the raw data the inverse transform of the periods longer than 26.2 years (the fifth harmonic). The shorter periods that remain are dominated by the 22-year period the approximate amplitude and phase of which we determined with a 10-year running mean filter. We suggest that this period may be related to the solar magnetic cycle. The low frequency data show a major dip centered around the period 1905-1910. These results should be considered in any analysis of global marine temperature for trends.

1. Introduction

Several long term marine data sets have been compiled in the last few years: Folland et al. (1984) used sea surface temperature (SST) and night marine air temperature (MAT) from the United Kingdom Meteorological Office Main Marine Data Bank for 1856-1981; Jones et al. (1986) used SST and MAT from the Comprehensive Ocean Atmosphere Data Set (COADS), for 1861-1984, and applied corrections based on coastal land station records; and Oort et al. (1987) used COADS data, with corrections for the uninsulated buckets used for temperature measurements before about 1940 as derived by Folland et al. These three investigations presented time series. Frequency domain analysis was performed by Folland et al. (1984), who stressed the presence of an 83 year variation, while a peak near 21 years in MAT went unremarked. The data by Folland et al. (1984) included data derived at MIT from the U.S. Navy Fleet Numerical Center records, the Consolidated Data Set (CDS), which was analysed by Hsiung and Newell (1983). The combined data, from the UK Meteorological Office and MIT, updated to 1986 and with revised corrections, has been compiled into the Global Ocean Surface Temperature Atlas (GOSTA (see Bottomley et al., 1989)). We have analysed seasonal mean anomalies of this updated nighttime MAT and SST for the globe and the two hemispheres for periodicities using forward and inverse Fourier transforms (FT), with the aid of Otoko, an interactive data analysis package and the results are presented here.

2. Results

Figure 1 shows unsmoothed frequency-domain representations of the seasonal mean global and southern hemisphere MAT anomalies from 1856 to 1986. The spectral estimator used is the sum of squares of the Fourier cosine and sine transforms divided by the number of

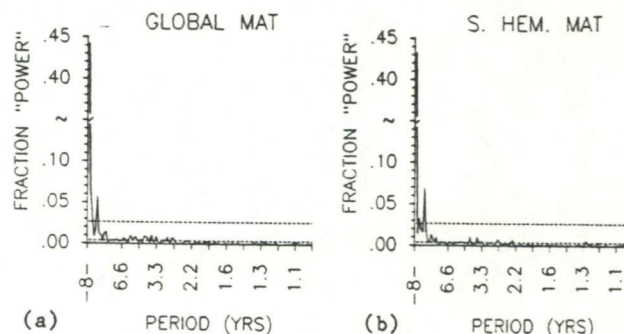


Fig. 1 FT's of a) global seasonal mean MAT, and b) southern hemisphere seasonal mean MAT, with 50%, and 99.9% confidence levels superimposed. Major ticks on horizontal axis are at every tenth harmonic. These plots show only the low frequency half of the spectrum, so the null spectrum does not represent an average of the data shown.

sampling points. The most obvious feature of these graphs, and of the northern hemisphere MAT FT and the three corresponding SST FT's (not shown), is the high-amplitude peak at the leftmost edge of the frame. This represents a variation which we cannot characterize, since its "period" is too long to be accurately determined from our 131-year record.

The next most striking feature of these plots is the second highest peak, at the sixth harmonic, which represents a period of 21.8 years. Upon visual inspection, this period appears to be significant, particularly in the southern hemisphere MAT FT. To determine the statistical significance of the southern hemisphere peak, our first step was to choose a "null spectrum", that is, a frequency-domain curve that represents the average level of the "noise" in the anomalies, in each frequency neighbourhood (WMO, 1966). We attempted to determine the degree and character of "persistence" in our data, and thus an appropriate null spectrum, by calculating the first few serial lag autocorrelation coefficients. The first four coefficients, for the southern hemisphere MAT record, are 0.73, 0.68, 0.62, and 0.62. They indicate the possible presence of persistence, but since they do not fall off exponentially with lag, they rule out a Markov "red noise" null spectrum, which is the only well-described null spectrum appropriate for data with substantial persistence. We applied the same technique to the global MAT anomalies with very similar results. In the absence of a well-characterized red noise null spectrum, we chose the "white noise" null spectrum, which is represented at each point in the FT by the average value of the entire FT.

Our next step was to compare the 21.8-year peak against the null spectrum, and to determine its statistical significance by consulting a table of the chi-squared distribution for two

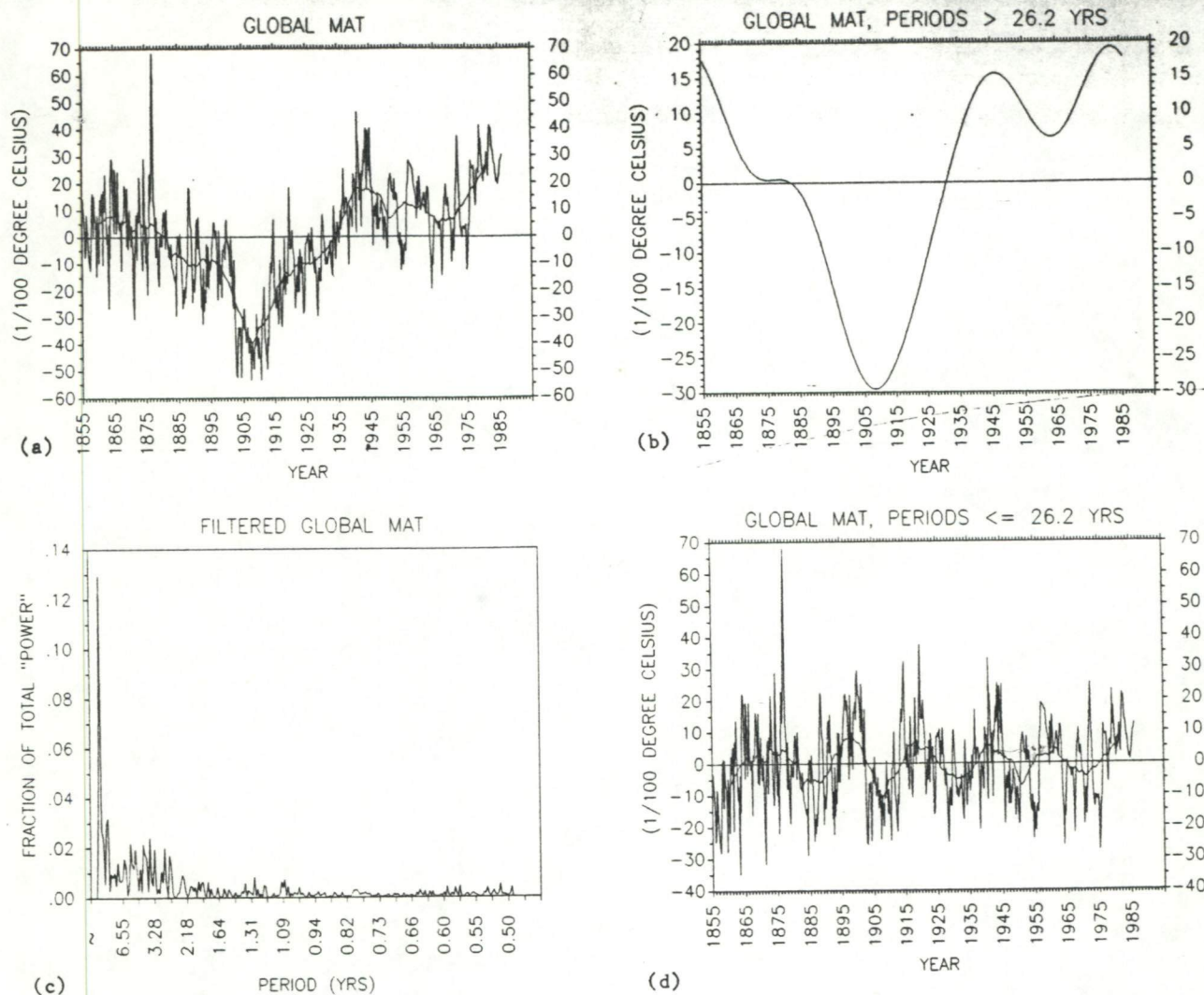


Fig. 2 Filtering process for global mean MAT anomalies: a) Raw data with 10 year running mean, b) periods greater than 26 years, c) FT of periods less than 26 years, d) periods less than 26 years with 10 year running mean. Ticks represent values from the last season of each year (October-December).

degrees of freedom (Jenkins and Watts, 1983). The southern hemisphere and global MAT FT's, in Figure 1, are shown with their 50% (null spectra), and 99.9% confidence levels superimposed. The 21.8-year peak is significant above the 99.9% confidence level in both the southern hemisphere and the global MAT plots.

It should be noted that amplitudes in an FT can be substantially influenced by artificial harmonics associated with nearby periods. The amplitudes of these false harmonics grow with the amplitude of the associated oscillation. To be certain that the 21.8-year period in global MAT was not an artifact of the FT, we subtracted from the raw global MAT data the inverse transform of the range of harmonics in its FT that represent all periods longer than 26.2 years (the fifth harmonic). The raw global MAT record with its 10-year running mean, the 26-plus year variations that we subtracted, the resulting high-pass filtered data with its 10-year running mean, and the FT of the filtered data are all shown in Figure 2. The 21.8-year variation dominates the high-pass filtered data and its effect can be detected in the unfiltered data. Although the global MAT FT showed only that there is a substantial variation in the data closer to the sixth (21.8 year) harmonic than to the fifth (26.2 year) and

seventh (18.7 year) harmonics, the high-pass filtered data show the actual period, phase, and amplitude of the oscillation. As determined from the 10-year running mean of the record since 1886, the period falls in the approximate range 20.7-21.7 years, and the peak to trough amplitude varies between 0.09 and 0.20 degrees. Note a major dip of about 0.5 degrees centered around 1910 in the 26-plus year variations.

We next proceeded to apply the same filtering technique to the southern hemisphere MAT anomalies, with similar results. The northern hemisphere MAT, and global and hemispheric SST FT's, do not show obviously significant 21.8-year peaks, but after application of the filtering technique described above, the approximately 21-year variation is evident in these four records also. Figure 3 shows the variation in the filtered southern hemisphere MAT record, where it is strongest. This variation, which shows good phase agreement between hemispheres, seems to be clearer in MAT than in SST, and appears most clearly in the southern hemisphere MAT record, and least clearly in the northern hemisphere SST record. Work in progress is revealing that this variation is detectable and substantially in phase in the Gaussian-smoothed high pass filtered records of

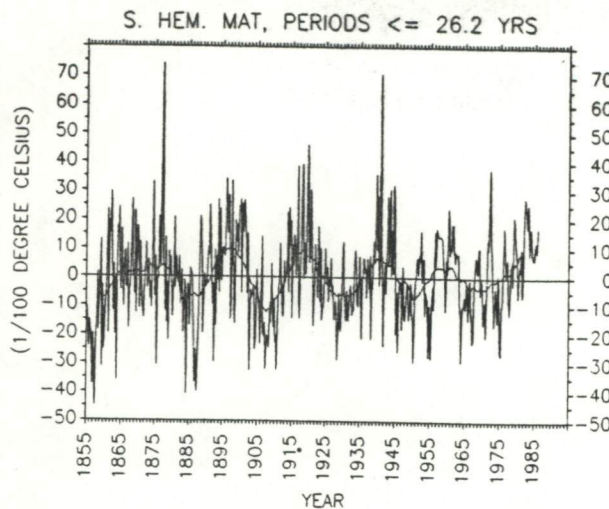


Fig. 3 Time series of periods less than 26 years, with 10-year running means of Southern hemisphere MAT anomalies.

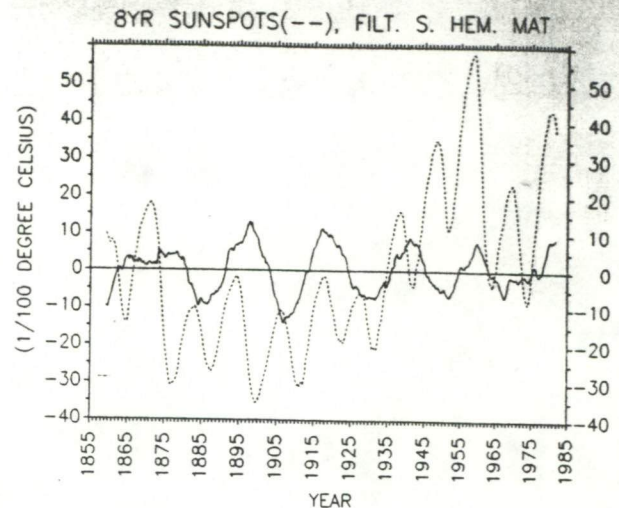


Fig. 4 Eight year running mean of periods less than 26 years in Southern hemisphere MAT (solid line) compared with the same running mean of seasonally averaged Zurich sunspots (dashed line).

most of the separate oceanic areas that make up the global MAT data set.

3. A Solar Relationship?

What is the cause of this prominent, apparently cyclic variation in global marine temperature? The near 21-year period observed here is close to that of the solar magnetic cycle, also known as the double sunspot cycle, the period of which, calculated over the 237-year Zurich sunspot record, is about 22 years. Figure 4 contains the 8-year running mean of the high-pass filtered southern hemisphere MAT anomalies, which shows the clearest near 21-year variation, compared with the 8-year running mean of the Zurich sunspot record over the same period obtained from the National Geophysical Data Center. It can be seen that, with one exception since 1869, consecutive clear high and low phases in the 21-year variation of southern hemisphere MAT correspond to consecutive peaks in sunspot activity. The exception, that of the long MAT high phase of the 1870's, could perhaps be the result of data problems, but it led us to consider the possibility of a corresponding irregularity in the solar magnetic cycle. In fact, the sunspot maxima of 1870 and 1882 do display an irregularity - they represent the only example in the sunspot record, between 1855 and 1886, where the polarity of the sunspot magnetic fields did not change between consecutive sunspot maxima (Willett, 1976). Hemispheric sign reversals in the solar bipolar magnetic field do not occur in phase with the sunspot field reversals, but rather they take place concurrently with or soon after sunspot maxima (Webb et al., 1984). Accordingly, a possible interpretation of Figure 4 is that cooling in MAT takes place during one phase of solar hemispheric magnetic polarity, and warming during the other. There is also a suggestion in Figure 4 of an inverse relationship between sunspot number and amplitude of the temperature cycle.

4. Discussion

Reid (1987) compared the 11-year means of sunspot number and global SST using an earlier version of the present data and found fair correspondence in the long-term variations. The 26-plus year variations of Figure 2 give a similar pattern to that of Reid. He suggested that solar

irradiance variations with an 80-90 year cycle may have been responsible, although other possibilities such as enhanced volcanic activity could also contribute and remain to be explored. Labitzke and van Loon (1988) found associations between the 11-year solar cycle, the quasi-biennial oscillation, and various atmospheric parameters in records since 1956. Muir (1977) and Colebrook (1977) related North Atlantic SST to the sunspot cycle. Kelly (1977) compared the sunspot cycle with sea level pressure variations in the North Atlantic-European sector of the northern hemisphere. Hanzlik (1931) was the first to suggest a relationship between the Earth's climate and the solar magnetic cycle. Stockton et al. (1983) related droughts in the western U.S. to this cycle. Willett (1974), in characterizing the climatic effects of the solar magnetic cycle, might be describing Figure 4 of the current report:

"The essential fact of particular significance about the double sunspot cycle is that, in middle and higher latitudes, ... maximum climatic anomalies, of opposite sign, occur with the approach of successive 11 year sunspot maxima."

The most obvious mechanism for any solar influence on global temperature is that of a variation in the solar irradiance. Data on the total solar flux is, however, very sparse. Fröhlich (1987) fits a trend to flux data, and concludes that the solar flux apparently increased at a rate of approximately 0.03% per year between about 1967 and 1980, and then began to decrease by about 0.02% per year. He suggests that the apparent flux variations may be related to the 22-year solar magnetic cycle. If Fröhlich's fit is a reasonable approximation to the actual flux, then a variation in solar flux corresponding to the 21 year global marine air temperature variation is not contradicted. Schatten (1988) and Lean and Foukal (1988), from measurements by the ERB and ACRIM radiometers, report a decreased irradiance of about 1 Wm^{-2} between 1981 and 1984, corresponding again to about 0.02% per year. The latter authors reconstructed irradiance back to 1954, based on observed sunspots and a contribution from solar faculae deduced from the 10.7 cm flux, and showed that maxima occurred in about 1958 and 1981. Although this sample is short term, it does not contradict the above

findings. A comparison between the rates of change of Fröhlich's solar flux, and that of the ten year mean of the filtered global MAT over the period 1971-1980, which is 0.012 K yr^{-1} , yields a sensitivity of about $0.12 \text{ K (Wm}^{-2})^{-1}$ when the factor of four between the flux outside the atmosphere and the mean surface flux is taken into account. The actual amplitude of the temperature cycle is reduced by the running mean process; thus this value is likely to be an underestimate of the sensitivity by a factor of about 1.5 (see Newell et al., 1974), which then yields an adjusted sensitivity of $0.18 \text{ K (Wm}^{-2})^{-1}$. Sensitivity values obtained by other techniques are summarized by Newell and Hsiung (1984) and range from 0.1 to $1 \text{ K (Wm}^{-2})^{-1}$. Other possible mechanisms for a solar influence on global temperature include variations in solar corpuscular radiation (see e.g. Tinsley, 1988).

5. Concluding Remarks

1) A near 21-year variation has been identified by FT analysis of marine temperatures for 1856-1986. It should be studied further to determine exactly where it is most prominent and why. Land station temperature records should be similarly examined.

2) The 21-year marine temperature variation shows good correspondence with the solar magnetic cycle; this correspondence could, of course, be due to coincidence.

3) Published solar irradiance values do not contradict the hypothesis that the total solar electromagnetic flux varies with a period and phase corresponding to that of the 21-year marine temperature variation. A comparison of solar flux and filtered marine temperature over the period 1971-1980 yields a sensitivity of $0.18 \text{ K (Wm}^{-2})^{-1}$.

4) The 21-year marine temperature variation must be considered in any estimation of trends in global marine temperature. For example, it can be seen from the plot of filtered global MAT anomalies in Figure 2 that after subtraction of the periods less than 26 years, which are dominated by this variation, there is no appreciable difference between temperatures at the beginning and end of the record.

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- Reginald E. Newell, Jane Hsiung and Wu Zhongxiang, Department of Earth, Atmospheric and Planetary Sciences, 54-1522, Massachusetts Institute of Technology, Cambridge, MA 02139.

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A DIGEST OF NEWS FROM MIT

MIT Reporter

Has the Globe Really Warmed?

Since the mid-nineteenth century, merchant-marine captains of all nations have been required to log air and water temperatures every six hours for weather services such as the British Meteorological Office. Crews on each watch have hauled water from the sea in standard buckets, dipped in standard thermometers, recorded the data, and, generally, radioed it back. The result is an incredible storehouse of information about global temperatures since the Industrial Revolution.

Reginald E. Newell, Jane Hsiung, and Wu Zhongxiang of MIT, along with colleagues from the "British Met," as they call it, have collected and analyzed these data. MIT Press intends to publish them in the *Global Ocean Surface Temperature Atlas*. One of the most striking results suggested by the data is that there appears to have been little or no global warming over the past century.

The advantage of ocean readings is that they are not contaminated by urbanization: the growth of structures and roads even in the small towns where many weather stations are located can raise temperatures, Newell explains. Unfortunately, ocean readings are not entirely reliable either. One of the chief problems is that prior to World War II, the buckets for collecting water were made of canvas. As it was hauled onto the deck, the water could be cooled by wind and heated by sun. Christopher Folland of the British Meteorological Office and Jane Hsiung attempted to correct for such problems, for example by measuring the cooling of the buckets at different wind speeds.

Gauging long-term temperature change required more analysis. First, Newell, Hsiung, and Wu needed to measure the cooling caused when volcanoes inject dust and gases into the atmosphere. They discovered an intriguing piece of work that measures the atmospheric "turbidity" from the dust over the past century. Beginning in the late 1800s, weather stations have used devices known as Campbell-Stokes sunshine recorders that burn a track in a paper card each day, indicating how long the sun was up. Researchers at the University of Mainz in West Germany collected and analyzed numerous such cards, noting particularly the beginning and end of the burn, which correspond to sunrise and sunset. Whenever atmospheric turbidity rose, the burn started later and ended earlier. The weather station in Sonnblick, Austria, almost unaffected by urban pollution at an elevation of 3 kilometers in the Alps, provides a record of turbidity back to 1887.

Newell, Hsiung, and Wu also assessed the periodic change in tropical temperatures caused by the El Niño-Southern Oscillation, a complex of ocean and air currents. Factoring out the effects of the El Niño-Southern Oscillation and the cooling caused by volcanoes, they found that global temperatures have warmed by only 0.2°C over the past century, which is within the estimated margin of error. In other words, the results leave open the possibility that there has been no warming at all.

In a paper based on the same data in *Geophysical Research Letters*, Nicholas E. Newell (Reginald Newell's son) joins the other researchers to examine a third temperature variation: a roughly 22-year cycle of warming and cooling that has occurred

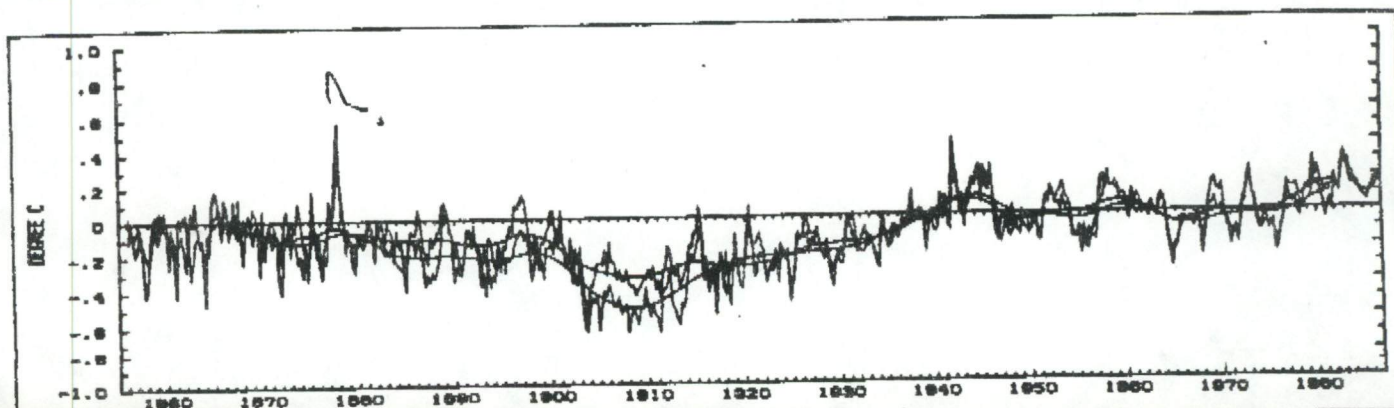
since 1856, when the marine data begin. This may be caused by the 22-year solar magnetic cycle, during which the sun's magnetic field changes polarity and then returns to its original state. The magnetic cycle is reflected in changing sunspot patterns. When the authors subtract from the basic temperature record all cycles of less than 26 years—the chief one being this 22-year warming-and-cooling pattern—they find "no appreciable difference" between temperatures in 1856 and 1986.

Both studies are at odds with some other research. For example, using land data that attempt to factor out effects of urbanization, James Hansen of NASA Goddard Space Flight Center and Sergei Lebedeff of Sigma Data Services Corp. conclude that the globe has warmed 0.5°C to 0.7°C over the past century.

The conflict is far from resolved. Unfortunately, despite all the models of how global climate may change, there is relatively little funding for research on the actual record. A case in point: though the *Global Ocean Surface Temperature Atlas* has passed peer review and been accepted by MIT Press, so far no sponsor has been willing to provide the modest subsidy that such a technical book often requires for publication—in this case \$60,000.

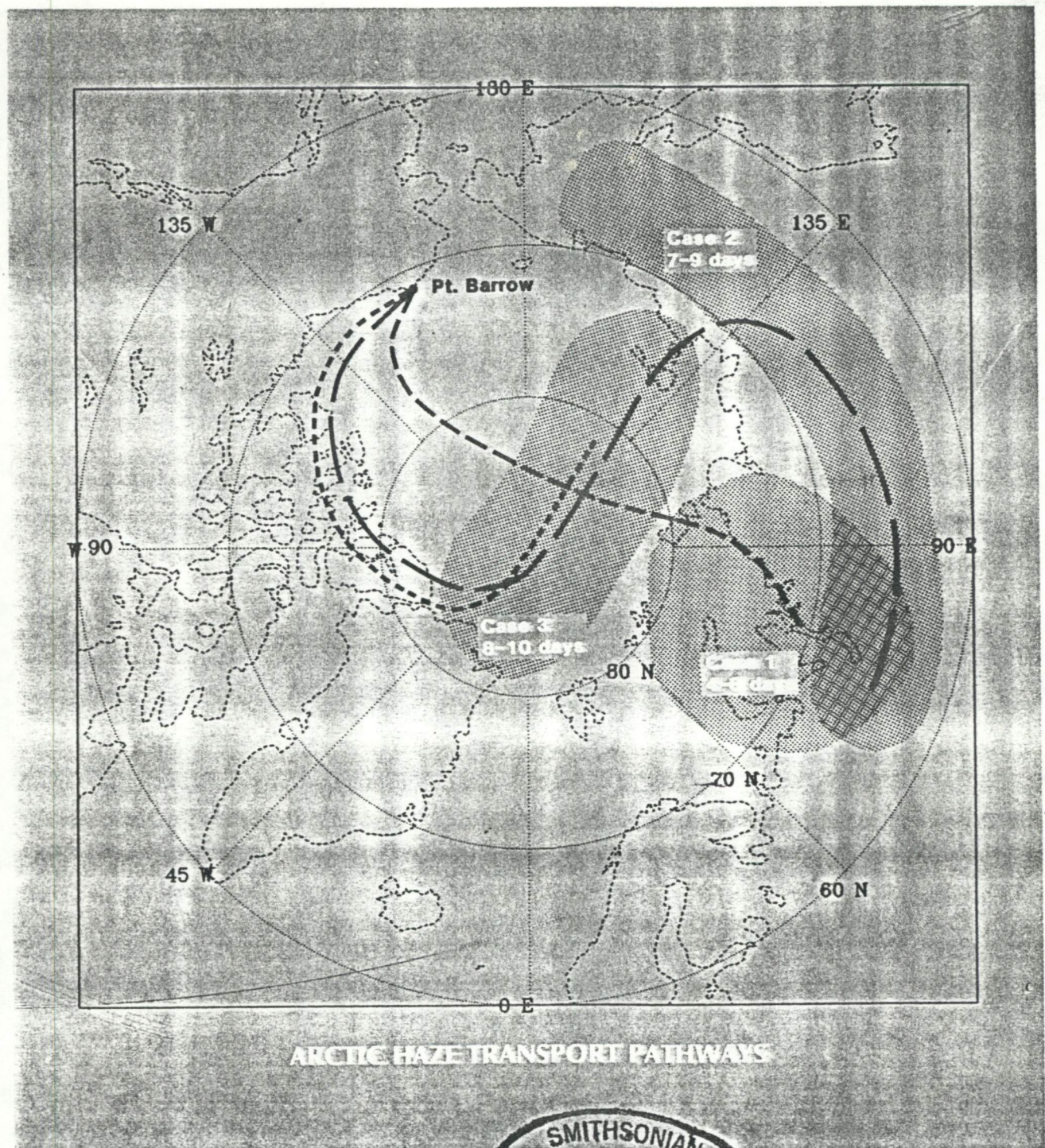
The Global Ocean Surface Temperature Atlas, accepted for publication by MIT Press, includes this chart plotting the sea surface temperature (blue line) and night marine

air temperature (red line) since 1856. Researchers who have analyzed the data conclude that there has been little or no overall warming.

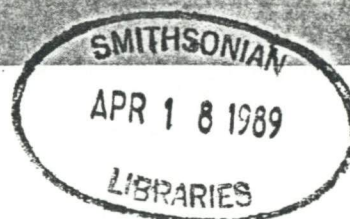


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AMERICAN GEOPHYSICAL UNION

GLOBAL CHANGE
By Robert M. White
President, National Academy of Engineering
Massachusetts Institute of Technology
May 17, 1989

The concept of global environmental change caused by the actions of humanity has now penetrated the consciousness of leaders at the highest levels of many governments in the world. The need for international action to arrest such change is equally clear. No ideology separates the concerns of Margaret Thatcher, Prime Minister of the United Kingdom; Mikhail Gorbachev, President of the USSR; George Bush, President of the United States; and Francois Mitterand, President of France. Proposals for action range from international research programs to monitor and predict the global environmental condition, to negotiation of conventions for establishing regulatory regimes to address causes of environmental deterioration.

In the United States many different legislative proposals are now being considered by Congress. *The high level of

public consciousness is signaled by the designation by Time Magazine of the planet Earth as the 1988 "Planet of the Year" in its year-end issue on the endangered Earth.

The problem is not new. *Forty years ago in 1948, as a graduate student at M.I.T., I was taken with the revelation of a global ecological crisis described in Our Plundered Planet, a book written by Fairfield Osborne, president of the New York Zoological Society. He wrote, "There is beauty in the sound of the words 'good earth.' They suggest a picture of the elements and forces of nature working in harmony. Nature may be a thing of beauty, but above and below and within its own immutable essences, its distances, its apparent quietness and changelessness, it is an active, purposeful, coordinated machine. Each part is dependent upon another, all are related to the movement of the whole. Forests, grasslands, soils, water, animal life - without one of these the earth will die - will become dead as the moon."

What has changed in four decades to raise new global

concerns about the deteriorating habitability of the planet Earth? What is the basis of this new public and political perception? What does our new scientific understanding tell us of causes and consequences?

The roots of our present planetary plight can be found in the post-World War II technological progress that resulted in industrial, medical, and agricultural advances simultaneously generating economic growth and intensified global environmental pressures. **Advances in medical science and technology as well as public health engineering of water supplies, sewage treatment, and waste disposal contributed to population explosions in poor nations, putting pressure on the carrying capacity of air, land, and water resources. The universal drive for economic security and growth led to the profligate use of natural resources and the introduction of new technologies. *The resulting expanded use of industrial and agricultural chemicals and the increased use of energy in both developed and developing nations intensified

environmental loadings.

Pesticides such as DDT protected human health and agricultural crops but visited unintended deleterious effects on wildlife and the environment. Explosive population growth changed land use patterns and destroyed natural habitats. Industrial disasters in the chemical and nuclear power industries punctuated growing concerns among the general public, governments, and environmental groups. *Oil spills yielded graphic images of environmental destruction.

Garbage scows wandering the oceans seeking a haven for dumping urban refuse pointed to the burgeoning waste disposal problem. Times Beach and Love Canal became synonyms for insensitive hazardous waste disposal. **The destruction of the great whales came to symbolize the lack of care for unique wildlife and the global ecology.

*In retrospect, the galvanizing event was the remarkable public impact of Rachel Carson's book The Silent Spring published in 1962, some twenty-five years ago. It touched a

responsive public nerve. It triggered political actions that still reverberate throughout the world to address environmental problems.

*The local nature of the problem first appeared as urban air pollution and contamination of local water resources.

*Atmospheric transport of the emissions from power plants and autos causing acid rain downstream, and the acidification of lakes in Europe and in the United States revealed the regional nature of atmospheric pollution. **People worried about forest die-back. Droughts in Africa, India, and the United States, with *vivid photos of starvation in the Sahel of Africa and *withered crops in the United States, raised concerns about the global climate and the habitability of the planet.

Science and technology were invoked both to understand the causes and to provide remedies. The photochemistry of urban air pollution was finally understood when Arie Haagen-Smit in California linked auto emissions of hydrocarbons and

the oxides of nitrogen as a source of the problem. Technology in the form of the auto engine design changes and the catalytic converter has partially addressed that problem. Science demonstrated that the oxides of sulfur and nitrogen emitted from power plants and automobiles are carried by the prevailing winds, and cause the acidification of lakes downstream and the loss of their ecological viability. Stack scrubbing technologies ameliorated the problem. Observations of the inexorable increase in the carbon dioxide (CO₂) content of the atmosphere correlated closely with data on the CO₂ release in the combustion of fossil fuels implicating fossil fuel burning as a principal cause. **Tropical forest destruction was also identified as a contributing cause.

Technology provided the means to assess the consequences. Large-scale computers could be used to simulate natural systems and model the changes in ocean and atmospheric characteristics and the responses of the atmosphere to changes

in its gaseous composition.

Space science and technology provided global monitoring systems and contributed greatly to our understanding. *The photos of the blue and white planet from spacecraft and from the moon brought home that we were all passengers on the "spaceship" Earth. And from satellites we could observe the *characteristics of the global biosphere *measure the extent of the ozone depletion in the Antarctic, *see the shifting patterns of biological activity in the oceans, *and comprehend the nature of the global cloud cover.

As this evidence of the deterioration of planetary conditions mounted, it became clear that our understanding of the dynamics of the planet and our ability to predict its future state required that all elements of the earth system, as Fairfield Osborne had suggested---the oceans, the atmosphere, the biosphere, and the solid earth---needed to be considered as parts of a single interacting and continuously changing earth system. The phenomena of concern were

interlinked not only by common physical, biological, and chemical forces, but also by common forces of economic and social development.

It is not surprising then that this heightening concern led to the rapid institutionalization of environmental action. In the United States, this institutionalization first took place in the early 1970s under President Nixon in whose administration the Council on Environmental Quality, the Environmental Protection Agency, and the National Oceanic and Atmospheric Administration were established. As we hear calls for a decade of the environment, it is important to recall that President Nixon signed into law the National Environment Policy Act on New Years day 1970 and called then for a decade of the environment. *With this institutionalization, there occurred the greatest outpouring of environmental legislation in the history of the country. Some twenty-eight federal laws addressing just about every environmental concern were enacted. These laws were accompanied by an explosive growth

of federal regulatory action. Judging by the number of pages in the Federal Register, regulatory actions increased eight fold over the past 25 years.

On the international front, 1972 saw the convening of the United Nations Conference on the Human Environment in Stockholm. For the first time, the full scope of global environmental concerns was laid out. Desertification and deforestation, land use and ocean pollution, climate and endangered species were addressed. This conference was the first international forum in which the conflict between the need for global environmental protection and the need for economic development in Third World nations, surfaced as a major issue between industrialized and developing nations. The first United Nations institution devoted to the protection of the environment---the United Nations Environment Program, now headquartered in Nairobi, Kenya---was established as a result of this conference.

As in the United States, the international environmental

movement was institutionalized. We witnessed new global conventions on ocean dumping; on protection of great whales; on trade in endangered species; and more recently, the Montreal Protocol to phase down the production of chlorofluorocarbons (CFCs) to protect the stratospheric ozone layer.

Climate change, which was to become the overriding global concern, saw its first international manifestation in the World Climate Conference of 1979, convened under the aegis of the World Meteorological Organization.

In 1983, the United Nations Commission on Environment and Development was established under the chairmanship of Gro Harlem Brundtland, Prime Minister of Norway. Its report, Our Common Future, brought into sharp focus the view that progress to protect the global environment would require a global bargain between the industrialized and developing nations that would enable developing countries to achieve their aspirations for economic growth, while simultaneously enabling

international action to protect the global environment.

Calls now are heard for conventions on a "Law-of-The-Air." Suggestions are made for granting supranational authority to the United Nations to regulate emissions and other actions of humanity which are environmentally degrading. Some express the view that ecological and environmental stability are essential to global security. The world scientific community, aroused by the implications of environmental deterioration for sustainable economic growth and species preservation, and stimulated by the great political visibility and momentum of the issue, has moved to formulate international global change programs. You will hear more about this program in the papers that follow.

The irony of the situation is that humanity, in pursuing the most fundamental activities necessary to advance human welfare---the growing of food, production of energy, provision of health care and pursuit of industrial development for economic growth---has created the spectre of environmental

deterioration that threatens to undermine this welfare.

This then is the general political, social, and economic context in which the search for understanding through science and remedies through engineering must take place. It is also the context in which both domestic and international policy formulation is now taking place. How to keep policy in line with the scientific base of knowledge is a challenge to both policymakers and scientists.

Although the phenomena that collectively constitute global change are interrelated, our knowledge of the causes and consequences of the individual phenomena vary widely. Two general scientific concepts join the diversity of phenomena that make up global change. The first relates to the physical environment and the ways in which humanity alters the geochemical circulation of elements such as carbon and sulfur in the global environment---the oceans, the atmosphere, the biosphere, and the solid earth. The second relates to the fragility of the ecological environment, which is so easily

disrupted by both geophysical and societal perturbations.

These two overriding scientific concepts---geochemical circulations and the delicate balance of ecosystems are linked by interactions between biological and geophysical systems.

The interactions between the geosphere and the biosphere are critical and fundamental to understanding environmental degradation. Just as the carbon dioxide and oxygen content of the atmosphere is controlled by biospheric processes, so desertification is the result of changes in precipitation and temperature.

In the real world, practical policies must address the causes and effects of individual phenomena. At the same time, we must recognize that they must be formulated in the context of their total environmental impact.

Let us examine the policy-knowledge equation as it relates to climate warming. *The causes---the increasing concentration of greenhouse gases such as carbon dioxide, CFCs, and methane---are well understood and documented by

precise global observations. The sources of the gases are well known to be the combustion of fossil fuels, the industrial use of CFCs, and the increased biological activity of burgeoning human and animal population and more intensive agriculture.

We are certain that the carbon dioxide content of the atmosphere has increased by 25 percent since the beginning of the industrial age and is now at about 350 parts per million. Reasonable projections suggest a doubling of the concentrations of greenhouse gases by the year 2050. The response of the global atmosphere to this change in gaseous composition can be assessed by simulating the ocean-atmosphere system using mathematical models. *With modern computers, the changes in global temperature and precipitation can be calculated. Estimates indicate that the global average surface temperature should increase from 2° to 5°C for a doubling of the infrared-absorbing gas content of the

atmosphere. The mathematical models are too primitive to provide reliable regional and local estimates, although they do project greater warming in polar than in tropical regions. The mathematical models are only approximations to the real world and significant uncertainties remain.

*We can also examine the response of the atmosphere using the global temperature records of the past century. These records reveal a roller coaster effect with increases and decreases over periods of decades, and a net increase of about 0.5°C over the past century. This rise would be consistent with the lower bound of the range of predicted temperature increases. Scientists disagree about the exact magnitude of this net increase.

There are sampling problems with the global temperature estimates, because the records are derived from a network established for purposes of weather forecasting, not for climate assessment. There are large areas of the world, such

as the oceans, where the data are sparse and where methods of observation have changed during the century. *Doubts about the reality of a temperature increase are raised by other temperature records, such as those over the United States since the turn of the century. These are among the most accurate and detailed temperature records in the world, and we find no evidence of a temperature change. This may also be a sampling problem since the United States represents only 2 percent of the earth's surface. The evidence for a climate warming based on temperature records is equivocal.

What do we know about the consequences of such a global temperature change for water resource availability, agriculture, sea level rise, etc.? A climate warming would reallocate climatic resources among the nations of the world, and the consequences would vary from nation to nation. There would be winners and losers. **Since we cannot predict the future state of the climate in detail, we are left with building scenarios to answer the question, "what if?" Such

scenarios can give us a range of possibilities but not predictions. We are in the realm of speculation.

In the case of climate warming, we have a good grasp of the causes, some confidence that mathematical models are portraying the general atmospheric response we can expect, uncertainty that the phenomenon is manifest in the empirical record, and speculation on consequences. What we need are "insurance" policies to protect against severe consequences, even though the probabilities may be quite uncertain. We should be considering policies that would be desirable for a range of environmental and economic reasons and would not foreclose other options, should projections of a climate warming be in error.

*Since fossil fuel combustion is one of the roots of the climate warming phenomena as well as other environmental problems, we should encourage greater energy efficiency; use of the least contaminating fossil fuels, such as natural gas; and invest in non-fossil energy sources, *such as publicly

acceptable and passively safe nuclear power reactors, and other alternatives, including photovoltaics, and biomass. Such prescriptions are easy to state as generalities, but it is a formidable task to translate them into actions that are both politically workable and economically meaningful, especially since actions are meaningful only if they are international in nature. Energy efficiency, for example, means raising fuel mileage for automobiles, efficiency in energy production, and industrial processes, and efficiency in end uses.

How effective would various measures to address the climate warming be? Bert Bolin, science advisor to the Prime Minister of Sweden, has made some interesting calculations. We can judge the effectiveness of measures to ameliorate the greenhouse effect by the reduction of the expected temperature increase, which we can choose to be 3.5°C , for purposes of argument. Dr. Bolin's results indicate that a drastic and

unrealistic immediate reduction in carbon dioxide emissions by 50 percent, would affect the projected temperature change by only 0.8°C . A reduction in emissions of CO_2 by 20 percent by the year 2000, as has been proposed in some legislation, would have only a marginal effect. What these numbers illustrate is the need to be clear about the effectiveness of proposed remedial actions when measured against the cost of implementing them.

Other remedial measures have been suggested. For example, tropical forest destruction at present contributes about 20 percent of the CO_2 increase. It has been suggested that arresting this destruction will help ameliorate the problem, and of course it would. But by how much? Again, Bolin's calculations show that even if we reforested half the forests that have been destroyed, the reduction in the temperature increase would be $0.1\text{-}0.2^{\circ}\text{C}$ ---an insignificant amount.

Whatever policies are adopted will require international agreement because consequences as well as causes will be unevenly distributed among all nations. International actions could only be undertaken by international convention. But, negotiation of such a convention would be explosively divisive between industrialized and developing nations. Countries such as China that are dependent on vast coal resources would be reluctant to sacrifice economic growth for global environmental goals especially in the light of uncertainties in our projection of the climate warming. A similar reaction could be expected from Brazil and other tropical forest nations in response to requests that curtail their economic and agricultural development for the sake of global environmental goals.

Stratospheric ozone depletion presents a different case. Here the preponderant scientific view is that an understanding of cause and effect is in hand. CFC's, inert in the lower atmosphere, release chlorine atoms under the action of

sunlight in the stratosphere, where photochemical processes result in a depletion of ozone. If CFC emissions are eliminated, the major cause of depletion is likewise eliminated.

Because there is a high degree of certainty, governments have adopted the Montreal Protocol. As of the beginning of 1989 there are 46 signatories and 31 ratifications. This convention restricts the production of CFCs by many countries of the world to prevent further ozone depletion. Further recent evidence for ozone depletion in the Antarctic stratosphere has resulted in proposals by President Bush, Margaret Thatcher, and many governments for a total phaseout of the production of CFCs. However, the restrictions called for in these international agreements and proposals are quite different from those that relate to greenhouse gases. Alternatives to CFCs are on the horizon, and economic consequences are limited to a few producing companies. The general consequences for society are mild. I do not mean to

minimize the costs to society of the redesign of equipment to accommodate CFC substitutes. My point is that in comparison with the costs and consequences of measures to ameliorate climate warming, those resulting from the phaseout of CFCs are minor.

Tropical forest destruction presents a wholly different situation. The causes and consequences are well known---the drive for economic development to accommodate population growth and provide reasonable living standards. The principal consequences of concern are the extinction of species and resulting reduction of biodiversity. The effect on climate warming is of second order. Thoughtful people throughout the world deplore the irreversible loss of species.

The destruction of tropical forests can be addressed only through actions by countries in which they exist. The governments of Brazil and other countries will arrest tropical deforestation only if they are convinced that it is in their self-interest to do so. If the consequences for global

climate are not significant, the argument must rest on the irreversibility of species extinction, the destruction of the global genetic pool, and the obligation of humanity to eschew irreversible damage to the planetary biosphere. Although economic arguments are made about the potential but unknown value of tourism, medicines, and other products, one must face the economic counter-argument of the value of development in these regions.

If we are serious about protecting the planetary environment, a bargain must be struck involving assistance in economic development in return for environmental protection. Swapping national debt for environmental protection has been suggested but received without enthusiasm by developing countries.

Regional environmental problems such as acid deposition and desertification present quite different issues to nations and policy formulation. Acid deposition is an environmental issue that is politically sensitive in the extreme---witness

the protracted negotiations between Canada and the United States and the situation in Europe. Desertification raises no such political sensitivity. It is universally recognized as an environmental condition that must be remedied. Both are transborder problems. The causes of both are well known, the one resulting from SO_x and NO_x emissions into the atmosphere, the other from land use pressures. Remedies are known for both. Solving the problem hangs up on costs, in one case economic, the other social.

The key point I make is that although it is important to recognize the interaction and close relations among the various environmental phenomena that constitute global change, it is also necessary to recognize that policy actions to ameliorate the consequences of these phenomena may very well be quite different. This suggests to me that in addressing the science of global change, we need to think of how to work more closely with the policy of global change. The two must

be kept in lockstep, the policy not being allowed to outrun the scientific base of knowledge, and the science being responsive to policy needs.

There is, in my opinion, much hope. The high present political visibility of the problem at present enables us to move ahead in ways that would have been impossible otherwise. Although I have some concerns about the visibility and momentum that now exists in the light of scientific uncertainties, it is a favorable condition that we should seek to shape. There is clearly a need and now a hope for a major international scientific effort to understand the basic physical and biological processes underlying all of the phenomena that contribute to global change.

There is an opportunity for the first time to come to grips with biogeochemical dynamics, ecosystem dynamics, and the dynamics of climate and hydrologic systems as well as the social and economic responses to climate and biospheric changes. We are fortunate indeed that new techniques for

monitoring and assessing the scientific problems are at hand. One need look no further than space observing systems that can now give us information on a worldwide basis about most of the global conditions that need study. A program of earth system science makes good sense as an investment in space technology. Our capabilities for simulating natural systems through the use of large-scale computers makes predictions of the future condition of the earth system feasible given an adequate understanding of the processes involved and an adequate base of observational data.

What is at stake in all of this is the fate of the global commons. We are all dependent on maintaining the habitability of the planet. We are approaching the time when there will need to be some form of international management of these global commons. This is the quintessential challenge to mankind for the next century.

The U.S. Global Change Research Program

"Decisive action is urgently needed to understand and protect the Earth's ecological balance. We will work together to achieve the common goals of preserving a healthy and balanced global environment in order to meet shared economic and social objectives and to carry out our obligations to future generations."

G-7 Environmental Statement, July 1989.

ISSUE: Decisions made in the next several months are critical to sustaining U.S. leadership in global environmental science and public policy debates. The President has an historic opportunity to capitalize on present public concern and scientific potential for realistic solutions by inviting world leaders to join him in the creation of an effective research program as a key first step in responding to problems of global environmental change. The President can use this opportunity to move the United States and the world toward the development of a truly predictive understanding of global environmental change -- an understanding which will form the basis for sound policy decisions now and well into the next century.

BACKGROUND: The past few years have seen a remarkable awakening on the part of humankind to the nature and ramifications of their actions on the complex workings of the global Earth system. The concerns that we presently hold about global environmental change result from constantly improving scientific insight into processes of change and their implications. Recent events, such as the discovery of the Antarctic "ozone hole" have led to calls for fundamental changes in the economic and social policies of both industrialized and developing nations. World leaders at the Paris Summit have made it clear that the issues presented by global environmental change are real; effective U.S. leadership will ensure the national and international response essential to our economic well-being and the health and safety of our people.

The body of scientific knowledge about global change is characterized by varying degrees of uncertainty. Proposals to develop an international framework convention on greenhouse gases are moving us rapidly into areas where scientific uncertainty is high. It is in the best interest of all nations to ensure that the details of those negotiations incorporate the best available scientific knowledge and to move to rapidly reduce the key uncertainties.

The United States has recognized that the effective linkage of public policy to scientific understanding requires a focused and

well-coordinated effort to provide reliable predictions and assessments of global environment change which will:

- o provide the information base to support policy decisions associated with changes in the global environment;
- o demonstrate a Federal commitment to address the scientific, technological and public policy issues associated with global environmental change by encouraging protective measures which have minimal economic or other adverse impacts; and
- o enhance our domestic economy and strengthen the competitive position of the U.S. in the world markets by increasing our confidence level in economic decisions with long-term consequences in areas such as agriculture, energy and industry.

The U.S. Global Change Research Program was established with the President's FY 1990 Budget to meet this scientific challenge by:

- o Establishing an integrated, comprehensive long-term program of documenting the earth system change
- o Conducting a program of focused studies to improve our understanding of the physical, geological, chemical, biological, and social processes that influence Earth system processes and trends on global and regional scales.
- o Developing integrated conceptual and predictive Earth system models.

RECOMMENDATION: It is recommended that the President strongly reinforce his commitment to addressing global environmental problems by:

- o endorsing a stable, long-term U.S. commitment to the aggressive science program embodied in the U.S. Global Change Research Program as the core of a strong international effort to provide the scientific foundation to support policy decisions.

In addition, the Administration should take steps to:

- o ensure the development, evaluation and implementation of global change impact assessments and response strategies;
- o provide effective mechanisms to ensure that new scientific insights are incorporated in policy decisions in a timely manner; and

- o encourage prudent actions (e.g., energy efficiency) which are justified on their own merit even when scientific understanding is incomplete.

PROS:

- o Demonstrates Administration's environmental leadership and credibility both domestically and internationally;
- o Provides sound scientific base required for near- and long-term policy decisions;
- o Strong scientific, public and Congressional support;
- o Fulfills the implied commitments embodied in the USGCRP Strategy document and FY 1990 Research Plan;
- o Provides both developed and developing nations with critical data for near-term (e.g., agricultural productivity) and long-term (e.g., climate change) issues;
- o Consistent with the President's commitment to a "mission to planet Earth" (July 20 speech commemorating the lunar landing); and
- o Provides the impetus for similar scientific commitments from other nations.

CONS:

- o Requires additional resources.

Draft of October 20, 1989
Prepared by CES Global Change
Working Group

THE WHITE HOUSE
WASHINGTON

August 29, 1989

MEMORANDUM FOR JOHN H. SUNUNU

FROM: D. ALLAN BROMLEY *DA*
SUBJECT: OSTP News Briefing on Global Change Report

With your concurrence, we wish to hold a news briefing on Thursday, August 31, at 3:30 pm in the auditorium of the Office of Thrift Supervision. At that time we would release the OSTP report entitled "Our Changing Planet: The FY 1990 Research Plan," introduce the Interagency group that prepared it, and answer any questions from the press on the report. (The report was sent to the President before the Economic Summit in Paris.)

This report represents a coordinated interagency plan for research and development on global change. Attached is a news release and the text of an oral statement that will be made by Robert Post of my staff, on my behalf. Also attached are copies of the report and the executive summary, separately bound.

This briefing is not intended to raise any policy issues on global warming. Rather, it would demonstrate that the Administration has already done a great deal of program planning on federally funded R&D to better understand and more confidently predict global change in the future.

We anticipate that the press will consist largely of science writers and others interested in global change.

Attachments (3)

cc: Steve Hart
Alixé Glen

THE WHITE HOUSE

WASHINGTON

August 29, 1989

MEMORANDUM FOR MARLIN FITZWATER

FROM: D. ALLAN BROMLEY *daB*
SUBJECT: OSTP News Briefing on Global Change Report

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cc: Steve Hart
Alixé Glen

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warming

Table 1
POTENTIAL BENEFITS FROM
THE ENERGY EFFICIENCY PLATFORM

Policy Proposal	-----SAVINGS IN 2000-----		
	Energy (1) (Quads)	Money (Billion \$)	Carbon Emissions (2) (Megatons)
Raise vehicle efficiency standards and gas guzzler tax/sipper rebates	2.0	12	41
Increase the gasoline tax and expand mass transit services	0.9	10	19
Encourage conservation in acid rain legislation	1.9	9	48
Reform utility regulation	3.8	14	94
Increase the efficiency of electricity supply	0.9	--	20
Appliance efficiency standards existing standards	1.2	6	25
new standards	1.1	5	25
Promote adoption of buildings standards and retrofit programs	1.2	5	22
Reduce federal energy use through life-cycle cost-based purchasing	0.2	1	4
Reduce industrial energy use through research, demonstration, etc.	2.7	13	58
Increase conservation R&D	=	=	=
TOTAL	15.9	75	356

(1) For reference, the U.S. consumed about 80 Quads in 1988. Projections of energy use in 2000 are given in Table 2.

(2) Units are million metric tons of carbon.

Table 2
OVERALL ENERGY USE, COST
AND CARBON EMISSIONS IN
1988 AND IN SCENARIOS FOR 2000

Scenario	Energy Use (Quads)	Energy Services Cost (1) (Billion \$)	Carbon Emissions (Megatons)
Actual 1988	79.9	416	1503
Frozen efficiency 2000	107.2	735	2010
EIA Base Case 2000	90.6	621	1699
High Efficiency 2000 (2)	74.7	546 (3)	1343

(1) Annual energy services cost expressed in 1988 dollars.

(2) Based on savings estimates from the policy proposals in this paper.

(3) Includes the levelized cost of additional conservation measures relative to the EIA base case, but excludes any tax impacts from the gasoline tax or economic impacts from the initiative to increase the efficiency of electricity supply.

NATIONAL ENERGY EFFICIENCY PLATFORM: DESCRIPTION AND POTENTIAL IMPACTS

Howard S. Geller
American Council for an Energy-Efficient Economy
Washington, DC

Energy Efficiency Issues Paper No. 2

July, 1989

I. Introduction

After over a decade of increasing national energy productivity, the overall energy efficiency of our nation has stalled and energy use is climbing rapidly. Energy use rose 8 percent in the past two years, in tandem with GNP growth [1]. This surge in energy use costs consumers tens of billions of dollars annually, contributes to rising oil imports, worsens acid rain and urban smog, and accelerates climate change due to the greenhouse effect.

Increasing emissions of carbon dioxide and other "greenhouse gases" are especially troubling given the possibility that, if current trends continue, the earth could heat up by around 2-5°C by the middle of the next century. Even warming at the low end of this range could dramatically alter rainfall patterns, reduce crop and forest productivity, and damage coastal areas [2]. A consensus is growing that reductions in greenhouse gases are urgently needed in order to minimize the risks associated with climate change [3]. Since the U.S. is responsible for about 21% of worldwide carbon dioxide emissions resulting from burning of fossil fuels, it must play a primary role in controlling CO₂ emissions.

Unfortunately, U.S. energy use and CO₂ emissions will continue to rise if new initiatives to promote greater energy efficiency are not adopted. The most recent base forecast by the Energy Department shows energy use increasing by 14% and CO₂ emissions by 13% between 1988 and 2000 [4]. However, rising energy use is not preordained. President Bush and the Congress should set a goal of eliminating growth in energy demand and reducing absolute CO₂ emissions during the next decade. This goal is technically feasible, it will save money, and it does not require personal sacrifice or economic stagnation. It will start the U.S. on a path whereby we substantially reduce our contribution to greenhouse warming over the long run, and it will set a positive example for other nations.

Achieving this goal requires a renewed commitment to energy efficiency, the most significant strategy for limiting climate change in the near-term [5]. As part of this commitment, new policies for improving the energy efficiency of our buildings, appliances, vehicles, and factories are needed. Comprehensive policies are called for given the challenge of limiting climate change as well as the federal government's failure to support greater energy efficiency in recent years.

The role of cloud microphysics in high-cloud feedback effects on climate change

C. M. R. Platt

CSIRO, Division of Atmospheric Research, Station Street, Aspendale, Victoria 3195, Australia

THE effect of clouds on the radiation balance of the Earth (cloud forcing) is such that, on average, they cause the mean surface temperature to decrease. When the climate system is perturbed, the cloud forcing may change and this change will exert a feedback on the system. Climate models predict that clouds will have an overall positive feedback effect, that is, their presence will tend to enhance any surface-temperature changes, as in the greenhouse effect for example. The models preferentially increase the amounts of high clouds and their optical depths and decrease the amount of low clouds. Here I look at the temperature dependence of the infrared emittance of high clouds using data from a ground-based lidar/radiometer and *in situ* aircraft measurements of cloud properties. I conclude that the infrared emittances of high clouds are less sensitive to changes in temperature than predicted by climate models, chiefly because the microphysics of cirrus clouds modifies the relationship between cloud optical depth and cloud ice/liquid water path, in ways not accounted for in the models.

The annual-global-mean radiative temperature $\bar{T}_s$ is controlled by the balance of the incoming solar radiation that is absorbed by the planet and the terrestrial infrared radiation, the intensity of which is proportional to $\bar{T}_s^4$. The value of $\bar{T}_s$ is ~ 255 K or -18°C , which would be the Earth's mean surface temperature ($\bar{T}_g$) without any atmosphere. $\bar{T}_g$ is actually much greater ($\sim 12^\circ\text{C}$) because atmospheric trace gases, such as CO_2 and H_2O , are strong absorbers of infrared radiation over the whole terrestrial infrared emission spectrum, except for an 8–13 μm 'window' which allows surface radiation to escape to space. The absorbing gases re-emit to space high in the atmosphere to give an effective radiating temperature of T_g . At the same time downward emission to the Earth increases the surface value well above $\bar{T}_s$ —the so-called greenhouse effect.

The value of $\bar{T}_g$ is further modified by clouds, which have a twofold effect. First, as they have a higher solar reflectance than most terrestrial surfaces, they reduce the radiation absorbed at the surface, thus reducing $\bar{T}_g$. Second, clouds absorb rather than scatter radiation at all infrared wavelengths, thus blocking emitted radiation from the surface in the atmospheric window, and re-emitting the radiation at cloud temperature, causing a reduction in planetary radiation to space and an increase in downwards radiation, thus increasing $\bar{T}_g$. The net magnitudes of the solar and infrared effects are such that low clouds cause a surface cooling, but high clouds result in surface warming^{1,2}. Averaged over all cloud types and amounts, there is a surface cooling and $\bar{T}_g$ is reduced by $\sim 18^\circ\text{C}$ from the cloudless value of $\sim 30^\circ\text{C}$ ^{3–5}. Thus, on average, clouds seem to reduce the equilibrium warming that is due to trace gases by a significant amount. From

these conclusions, however, we cannot predict what will happen when the climate is perturbed by an increase in CO_2 , for example, because different cloud types may not change their optical properties equally.

Incorporation of cloud properties into global climate models (GCMs) is still rather crude so that prediction of the effects of clouds on climate change is only approximate. Some GCMs do now carry interactive-cloud schemes so that clouds can respond to climatic perturbations^{6–9}, but only cloud amount can vary. Recently, however, variable cloud liquid-water content, linked to cloud solar reflectance and infrared emittance, has been incorporated^{10,11}.

The above GCMs have consistently shown that an effective doubling of CO_2 increases the high-cloud amount but decreases the lower-cloud amount. Both these changes will cause a further increase in $\bar{T}_g$, that is, a positive feedback. Calculations¹⁰ also show that the cloud liquid-water content increases everywhere. Although there is still a net planetary warming, $\bar{T}_g$ actually decreases¹². Roeckner^{10,11} performed a 20-year simulation using a GCM with coupled mixed-layer ocean and sea-ice models. The governing equations were solved at three vertical levels (850, 550 and 250 hPa) for a control model and for a model perturbed by 2% increase in the solar constant—roughly equivalent to a CO_2 doubling. They extracted changes in cloud quantities such as cloud liquid-water content (calculated from moisture continuity) and infrared emittances.

Here I compare the simulation^{10,11} results at 250 hPa with two sets of results based on observations of cirrus clouds that have recently become available. These data were taken at a wide range of cirrus temperatures, so that I could calculate the temperature derivatives. One set of data comprises particle size distributions of cirrus clouds measured *in situ* from an aircraft at different atmospheric levels and temperatures and in a number of cirrus clouds¹³. The data show that the cloud infrared absorption coefficient, the ice/water content and the cloud-particle mode radius all increase with temperature^{14,15}. The other set of data comprises remote observations on cirrus with a surface lidar and passive infrared radiometer¹⁶. These data include cloud infrared vertical-beam emittance, cloud depth and infrared absorption coefficient. The temperature variation of the absorption coefficient is similar to that found in the aircraft measurements. Some preliminary examinations¹⁷ of feedback have been done using the combined data sets.

To compare model and observational results the above observed quantities must be related to the variables of the model. For example, the measured cloud vertical-beam emittance ϵ_a (ref. 16) is the radiance in a narrow cone of angles in a direction perpendicular to the cloud divided by the blackbody radiance at cloud temperature and in the same cone. The diffuse-flux emittance ϵ in ref. 10, however, refers to the total flux emitted at all angles from the cloud as measured by a horizontal detector, divided by the total cloud blackbody flux¹⁸. Now ϵ_a can be written $\epsilon_a = 1 - e^{-\delta_a}$ where δ_a is the cloud absorption optical depth. It can be written as $\delta_a = K_a L = \sigma_a h$ where K_a is a mass absorption coefficient, L is the integrated vertical ice (or water) path, σ_a is the volume absorption coefficient, h is the cloud depth and I assume vertical homogeneity in the cloud. L is related

TABLE 1 Cirrus mean cloud-water content and infrared absorption parameters deduced from lidar/radiometer and cloud microphysical measurements

T ($^\circ\text{C}$)	h (km)	ϵ_a	δ_a	σ_a (km^{-1})	K_a (g^{-1}m^2)	L (g m^{-2})	dL/dT ($\text{gm}^{-2}\text{ }^\circ\text{C}^{-1}$)	W (g m^{-3})
-70	1.30	0.085	0.089	0.065	0.133	0.67	0.062	5.1×10^{-4}
-60	1.78	0.130	0.139	0.073	0.084	1.65	0.154	9.3×10^{-4}
-50	2.27	0.215	0.242	0.107	0.051	4.75	0.440	2.1×10^{-3}
-40	2.76	0.310	0.371	0.134	0.032	11.6	1.08	4.2×10^{-3}
-30	2.67	0.425	0.553	0.207	0.019	28.4	2.660	1.1×10^{-2}

Data are deduced from measurements reported in refs 13–16.

TABLE 2 Comparison of emittance and water-path changes derived in this study with those predicted in ref. 10

	T (°C)	ΔT (°C)	ϵ	$\Delta \epsilon$	L (g m ⁻²)	ΔL (g m ⁻²)
11° S*	-43	+7	0.42	0.18	—	5
11° S†	-43	+7	0.482	0.093	8.4	6.8
45° S*	-48	+5	0.42	0.24	—	4
45° S†	-48	+5	0.395	0.087	4.7	3.7

* Ref. 4.

† Data from lidar/radiometer and cloud microphysical measurements¹³⁻¹⁶.to ice/water content W by $L = Wh$ so that

$$K_a = \sigma_a / W \quad (1)$$

Now σ_a and W are proportional to the square and cube of the particle radius, respectively, and so¹⁷ $\sigma_a = 2W/\pi r_e$ or $K_a = 2/\pi r_e$ where r_e is the cloud-particle mode radius. Thus, σ_a depends on both W and r_e .

As the simulation results give the changes of emittance it is instructive to see how changes in ϵ with T relate to the other quantities. As ϵ is a function of ϵ_a

$$\frac{d\epsilon}{dT} = \frac{d\epsilon}{d\epsilon_a} \frac{d\epsilon_a}{dT} \quad (2)$$

or

$$\frac{d\epsilon}{dT} = \frac{d\epsilon}{d\epsilon_a} (1 - \epsilon_a) \left(K_a \frac{dL}{dT} + L \frac{dK_a}{dT} \right) \quad (3)$$

Various quantities derived from the observational data are shown in Table 1. Values of ϵ_a , h and σ_a were obtained from the lidar and radiometer studies¹⁶ and values of K_a were obtained from the cloud-particle spectra¹⁵. Values of σ_a previously calculated¹⁵ from cloud-particle spectra agreed well with the lidar/radiometer data¹⁵. Values of K_a from the cloud-particle spectra were extrapolated for temperatures $< -55^\circ\text{C}$. For consistency, values of W were calculated from equation (1), using the values of σ_a and K_a in Table 1. L was then calculated using the observed values of h .

Table 1 illustrates the large increases in W and L with temperature observed in high clouds. The mass absorption coefficient K_a decreases significantly, however, because the cloud-particle mode radius also increases, with the result that increases in σ_a (or δ_a) with temperature are much less than the increases in W (or L). (That is, the last term on the right-hand side of equation (3) is negative). These results imply that absorption (or extinction) must be parameterized in terms of r_e as well as W .

Changes in ϵ and L with temperature are compared with the model results¹⁰ at 250 hPa in Table 2. The temperatures shown in column 2 were taken from ref. 19. As the temperature changes ΔT quoted in ref. 10, were appreciable, comparison values of $\Delta \epsilon$ and ΔL were obtained from plots of ϵ and L as a function of T (using the data in Table 1) rather than from equation (3). The initial values of L are not quoted in ref. 10.

There is reasonable agreement between the values of ΔL , but values of $\Delta \epsilon$ obtained from the simulation seem to be too high by factors of two or three. Stephens's parameterization²⁰, used in ref. 10, is considered quite adequate for lower-boundary-layer clouds and some deeper water clouds, but does not take account of the large changes in r_e , and therefore in K_a , in cirrus clouds. The values of K_a used in ref. 10 were apparently too high, implicitly neglecting the observed decrease in K_a with temperature. Somerville and Remer²¹ introduced the inclusion of liquid water into GCMs but they also made δ proportional to L only. My results show the necessity of allowing for r_e .

Apparently Roeckner's calculated values of ΔT that are due to cirrus cloud are too large, because the increase in cirrus

emittance is smaller than he predicted. As pointed out^{10,12}, the warming at cirrus altitudes will be counteracted by a net cooling at the surface because of a loss in solar radiation. According to Schlesinger¹², the overall radiative change is still positive, but my results indicate that this may not always be the case. □

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Reconstruction of tree-line vegetation response to long-term climate change

Serge Payette, Louise Filion, Ann Delwaide & Christian Bégin

Centre d'Études Nordiques, Université Laval, Sainte-Foy, Québec, Canada, G1K 7P4

KNOWLEDGE of the vegetation response to climate change is necessary to assess and predict realistic ecosystem development in the anticipated, CO₂-induced warmer world, particularly at high latitudes where greater warming is expected¹⁻³. Reconstruction of vegetation development over the past 1,000 years may be helpful in this respect, because this period was characterized by contrasting climatic conditions⁴⁻⁹. Here we report the reconstruction of wind-exposed, tree-line vegetation associated with long-term climate change in northern Canada, using tree-ring and growth-form analyses of spruce subfossils. Three major types of growth form within the exposed, but stable, lichen-spruce community successively predominated in response to climate forcing: high krummholz (dwarf spruce, <2-m high) with scarce small (>2-m high) trees (AD 1305-1435, cool period), trees (>2-3 m high) and high krummholz (AD 1435-1570, warm period) and low krummholz (≤ 50 cm) (little ice age to present: AD 1570 onwards, cold period and present climate, respectively). Whereas the expansion of a marginal lichen-spruce woodland climaxed during the late Middle Ages (AD 1435-1570), present development of a low-krummholz vegetation at these sites seems to be out of phase with the twentieth century warming. This suggests that ecosystem recovery to global warming is not straightforward, depending on the nature of vegetation structure present at the time climate change occurred. The implications of such ecosystem resilience for the detection and monitoring of the expected CO₂-induced warming is discussed, particularly for the climate-sensitive arctic and subarctic regions.

High-latitude tree-line sites are susceptible to changes in climate, where summer temperature¹⁰ and winter conditions¹¹⁻¹³ represent the main restrictive factors for tree growth. Vegetation responses to climate change at such marginal sites involve com-

plex interactions between the two closely related processes of sexual reproduction and phenotypic plasticity in tree species. In black spruce (*Picea mariana* (Mill.) BSP), the dominant tree species in subarctic Canada¹⁴, sexual reproduction occurs mostly in monopodial trees with normal stems, whereas krummholz are generally unable to produce a large number of cones and viable seeds¹⁵. The reaction of spruce to climate change may thus be different according to the type of dominant growth forms prevailing at the time the climate change occurred.

Old-growth tree-line vegetation that escaped fires during the past centuries in northern Québec is made of living and dead black-spruce stems of all ages^{16,17}. Depending on the microsite conditions, dead stems remain undecomposed for several hundred years, 400–600 yr being the average apparent residence time for logs found at the soil surface. This provides the opportunity to reconstruct the recent stand history from living and dead material of wind-swept, old-growth coniferous sites in the Boniface River/Busk Lake area of northern Québec (57° 50' N, 76° W). The area has a rolling, low-plateau topography made of small hills (the so-called upland sites: 150–200 m) protruding the lowlands (115–125 m). Present vegetation at all of the study sites is typically lowland and upland tundra—scattered or dense low krummholz, with dwarf birch (*Betula glandulosa* Michx.) and fruticose lichens. Small forest stands are located in snowy (80–150 cm of snow), protected sites. At upland sites, the stunted spruce (<30–50 cm high) have very narrow tree rings which are difficult to measure. The average snow depth rarely exceeds 30 cm, as suggested by mean height of woody vegetation. In contrast to the living vegetation in upland sites, leaning dead spruces are abundant at the soil surface and include several types of shrubby and arboreal growth forms. Tree subfossils in wind-swept lowland sites, however, are very infrequent. Spruce stumps were recovered from mires and, during a period of exceptionally low water level, from lakes.

Four sets of data were sampled. The first two sets included subfossil trees and the third set comprised subfossil high krummholz. Together these formed a mixed subfossil population that lay on the ground of exposed, low-krummholz communities situated on five small hilltops (Fig. 1). The fourth set, composed of large subfossil tree stumps recovered from lowland mires and lakes within a 50-km² area, was sampled for a comparative tree-ring and growth-form analysis with upland subfossils. Growth form, total height and winter damage (indicated by multiple-stem and branch leaders) of dead spruces were evaluated for all specimens found on the small hills presently under severely exposed snowless conditions (Fig. 1). A Henson micrometer (0.01-mm precision) was used for tree-ring measurements of finely sanded stem sections. Standard tree-ring techniques¹⁸ were applied only to stem disks without reaction wood¹⁹ (eccentric tree ring development in the direction of stems tilted towards the ground). Although missing or incomplete tree rings were common, cross-dating of spruce wood was facilitated by the available light-ring (tree rings without latewood cells or showing reduced latewood-cell development) chronology²⁰ supplemented by new records of light-ring years, especially between AD 1305–1560 (A.D., L.F. and S.P., unpublished data). Because an unknown proportion of outer rings was removed from dead stems by weathering and decomposition, reported dates of stem mortality may be in error by 10–20 yr. Four tree-ring chronologies based on spruce growth forms were deduced: upland-tree chronology from disks above the inferred snow-air interface (AST (above-snow tree), AD 1372–1799, including 34 radii from 21 samples), upland-tree chronology from disks below the inferred snow-air interface (BST (below-snow tree), AD 1350–1803, including 28 radii from 16 samples), upland-krummholz chronology from disks below the inferred snow-air interface (BSK (below-snow krummholz), AD 1305–1811, including 23 radii from 15 samples) and lowland-tree chronology (LT, AD 1425–1789, including 13 radii from 7 samples). In Fig. 2 we present curves of the mean width of tree

rings of these spruce growth forms, which give direct evidence of past climate change.

Cross-dating of subfossil stem parts used in the tree chronologies indicate that normal trees developed at both upland and lowland sites between AD 1435 and 1570 (Fig. 2, AST and LT time series). Periods of faster growth recorded in the AST chronology around AD 1435–1450, 1495–1525 and 1550–1570 coincided with active upright-stem development above the critical snow-air interface, whereas only small stems developed around AD 1375, 1585 and 1740. Based on the frequency of stem development above the inferred snow-air interface, upland sites were occupied by lichen-spruce communities made up mostly of high krummholz with scarce small trees between AD 1305 and 1435. Marginal woodlands dominated by high krummholz and larger trees expanded between AD 1435 and 1570. According to the morphological features of subfossil spruces, the average snow-air interface was in the range 50–80 cm above the ground surface before AD 1570, after which it decreased steadily to its modern level of 30 cm. As stem development above the inferred snow-air interface also declined after AD 1570, clearly shown by the tree-ring patterns in all tree chronologies, stem dieback intensified particularly during the

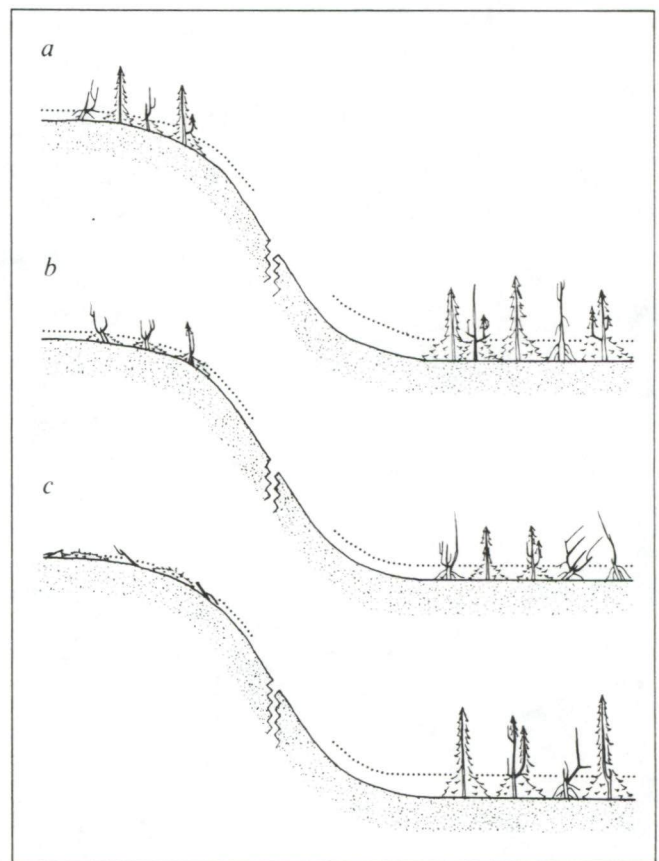


FIG. 1 Vegetation reconstruction in exposed tree-line sites from a, late Middle Ages to b, little ice age and c, the present, in comparison with spruce development in snow-protected forest sites during the same period (ref. 16 and C.B., unpublished data). Presence or absence of vertical stem development above the snow cover (dotted line) constitute the best indication of present and past climatic conditions in cold subarctic environments. Sampling was stratified according to position above and below the inferred snow-air interface. Three data sets were used in the reconstruction. The first two sets associated with subfossil trees (in black) were composed of tree-stem sections or disks sampled respectively below and above the inferred snow-air interface shown in c, as determined by morphological traits such as abrupt changes in stem diameter and multiple stem leaders. The third set was made of subfossil krummholz (in black) sections all located below the inferred snow-air interface. Vegetation reconstruction was inferred from cross-dated subfossil spruces, which show distinct growth-form patterns (krummholz and tree) through time.

17th century (Fig. 2, AST and LT time series). From AD 1570–1580 onwards, a period corresponding to the onset and full development of the little ice age, the rate of stem dieback became considerably higher than production of new above-snow stems. Only snow-protected parts of tree and high krummholz survived at these sites until the 18th and 19th centuries, when new growth was in the form of small, horizontal spruce layers (Fig. 2, BST and BSK time series). Because sustained dieback proceeded continuously during this period, marginal lichen-spruce woodlands that developed during the AD 1435–1570 period progressively changed towards exposed, snowless, low-krummholz communities. Most of the creeping spruces which dominate present upland vegetation are survivors, through the process of layering, of 16th century spruces.

Tree-ring patterns of the four chronologies were closely associated with the temporal development of the spruce growth forms (Fig. 2). Highly significant correlations (0.01 level) were found between all time series (r ranging from 0.61 to 0.74, except between the BSK and LT chronologies where $r=0.46$). The strongest associations are between the tree time series, which indicate quite similar growth conditions associated with the climate and growth habit. The lowest mean ring width and standard deviation of ring widths were from the BSK time series (0.18 ± 0.06 mm), which expressed the slow development of high krummholz with their foliage and growth meristems mostly concentrated less than 1 m above the ground. Faster growth and higher variability of ring width in the AST (0.21 ± 0.10 mm).

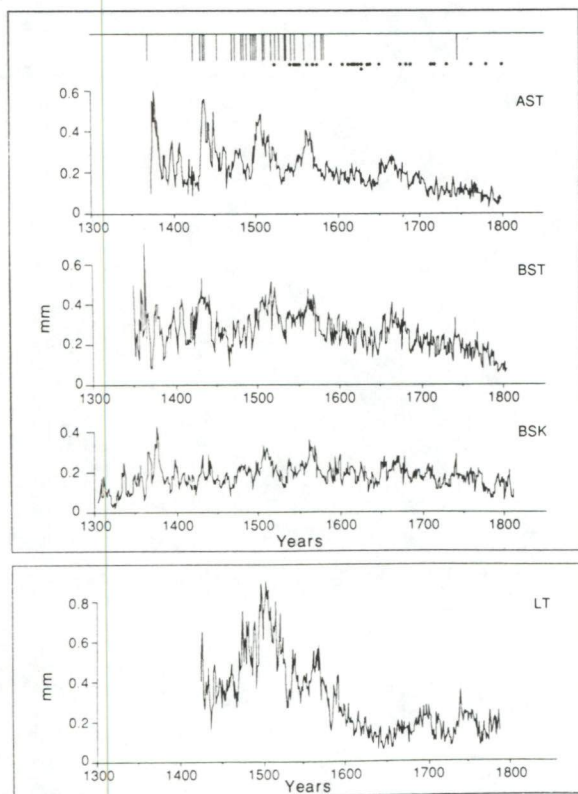


FIG. 2 Time series of ring widths from upland and lowland sites at the tree-line. Upland-tree chronologies: AST (disks sampled above the snow-air interface) and BST (disks sampled below the snow-air interface). Upland-krummholz chronology: BSK (disks sampled below the snow-air interface). Lowland-tree chronology: LT, shown separately for comparison. Vertical bar: tree-ring date of onset of individual stem development above the snow-air interface. Black dot: maximum tree-ring date (apparent age +20 yr to account for the removal of outer rings by weathering and decomposition) of dieback of individual stems above the snow-air interface.

BST (0.26 ± 0.09 mm) and LT (0.31 ± 0.19 mm) chronologies reflect the irregular periods of stem growth and dieback. Time-series mean ring widths calculated for the two major growth periods, as defined by tree development (before AD 1570) and tree dieback (after AD 1570), indicated relatively rapid growth before AD 1570 among tree chronologies (AST: 0.28 ± 0.10 mm before AD 1570, 0.16 ± 0.06 mm after AD 1570; BST: 0.31 ± 0.09 mm before AD 1570, 0.22 ± 0.07 mm after AD 1570; LT: 0.48 ± 0.16 mm before AD 1570, 0.18 ± 0.07 mm after AD 1570), whereas krummholz growth (BSK) remained fairly constant throughout (0.18 ± 0.07 mm and 0.18 ± 0.05 mm, respectively).

Such direct responses of upland lichen-spruce communities to climate change may help to predict future directions of vegetational change in the climate-sensitive Arctic and subarctic areas. A major feature to consider is the site sensitivity and the associated vegetation resilience to climate disturbance. Comparison of developmental sequences among strategic sites positioned along a wind-exposed toposequence indicate that, before the onset of the little ice age, both exposed (this study) and protected sites¹⁶ (C.B., unpublished data, as shown in Fig. 1) responded positively to warming by favouring tree expansion and development of open woodlands, whereas severely exposed sites (composed of living and dead spruces showing the same prostrate, low-krummholz growth form) remained fairly stable from the late Middle Ages to the present (Fig. 1). Thus, differential vegetation responses to climate change only occurred during this century at the two former sites. Although protected lichen-spruce sites showed a shift from high krummholz to forest from the little ice age to 20th century, most of the exhausted creeping krummholz in exposed lichen-spruce sites have been unable to react positively to present warming. This situation may be explained by a marked difference in vegetation resilience between the lichen-spruce ecosystems. High krummholz located in protected sites were able to catch drifting snow and maintain the snow cover above the critical level for spruce survival during the little ice age. At exposed sites, the inability of creeping spruces to control the snow-drift environment was a key factor enhancing snowless conditions. Such conditions prevented seed production and seedling establishment in upland sites, whereas in protected sites large seed bearers were already present when recent warming started¹⁶. Whether the shift from snow-rich to snowless conditions in upland sites was associated with an exacerbated wind-disturbance regime caused by death of large pre-little-ice-age spruces unable to trap blowing snow, or to a major change in winter climate, or to both influences, is a question that deserves consideration.

Our data suggest that vegetation responses to global warming are not as straightforward as one may expect, as it is necessary to sort out the magnitude of climate change and the importance of autogenic control involved in ecosystem resilience. Vegetation resilience to environmental change, as reported here along a wind exposure gradient, constitutes an important ecosystem attribute. The amplitude and duration of recent warming were probably not large enough to compensate for the detrimental effects of the long-lasting cooling of the little ice age on exposed sites. Accordingly, recovery of the stand to its state before the little ice age would require a much milder winter climate in order to significantly increase winter survival of buds and needles, a necessary step to achieve stem development, cone production and spruce regeneration. Although recent climatic data indicate sustained global warming²¹ during this century, no conclusive evidence of a positive vegetation response to such warming has yet been identified at these exposed tree-line sites. A reliable test for assessment of substantial global warming associated with rising atmospheric carbon dioxide at the arctic-subarctic transition, that is, warming that could overcome current wind and snow effects, would thus be from direct field evidence of vertical growth-form development leading to a type of ecosystem at least similar to that of the AD 1435–1570 period.

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Earthquake recurrence and risk assessment in circum-Pacific seismic gaps

Wayne Thatcher

US Geological Survey, Menlo Park, California 94025, USA

THE development of the concept of seismic gaps, regions of low earthquake activity where large events are expected, has been one of the notable achievements of seismology and plate tectonics. Its application to long-term earthquake hazard assessment continues to be an active field of seismological research. Here I have surveyed well documented case histories of repeated rupture of the same segment of circum-Pacific plate boundary and characterized their general features. I find that variability in fault slip and spatial extent of great earthquakes rupturing the same plate boundary segment is typical rather than exceptional but sequences of major events fill identified seismic gaps with remarkable order. Earthquakes are concentrated late in the seismic cycle and occur with increasing size and magnitude. Furthermore, earthquake rupture starts near zones of concentrated moment release, suggesting that high-slip regions control the timing of recurrent events. The absence of major earthquakes early in the seismic cycle indicates a more complex behaviour for lower-slip regions, which may explain the observed cycle-to-cycle diversity of gap-filling sequences.

The seismic gap concept originated from the work of Fedotov¹ and Mogi², who examined the relation between seismicity and the occurrence of great earthquakes on the margin of the north-west Pacific. They noted that over a time interval of about 30 years, the spatial distribution of background seismic activity defined a long linear belt interrupted by a number of conspicuous gaps. The seismicity belt was comprised of the aftershock zones of individual great earthquakes, which outlined adjoining regions but did not significantly overlap. In the areas of low activity, the seismic gaps, there had been no large or great earthquakes during the preceding decade or more. Historical records indicated that great events had occurred in the gaps during the late 19th or early 20th centuries, however, and several of the gaps did rupture in the years 1952-1963. Fedotov and Mogi recognized the forecasting implications of this observation and suggested that large events should be expected in the remaining gaps. Between 1968 and 1973 there were major earthquakes³ in four of these gaps.

The discoveries of plate tectonics immediately supplied a simple rationale for these empirical inferences⁴. The long linear seismic belt defined the boundary between the Pacific and Eurasian lithospheric plates. The gaps represented unruptured segments in locked frictional contact where relative plate motion was building up elastic stress that would ultimately be relieved in great earthquakes. These conclusions quickly led to a recognition that the seismic-gap concept could be applied to make qualitative assessments of long-term seismic hazard on major plate boundaries throughout the world³⁻⁶. These applications have been remarkably successful: up to 1988, 13 identified circum-Pacific seismic gaps have subsequently ruptured in large or great earthquakes⁷.

During the past ten years, research has increasingly been directed towards quantifying the timing of long-term earthquake predictions and integrating these estimates into a probabilistic framework⁸⁻¹³. At the same time, new work has highlighted several unresolved issues which limit the confidence that can be placed in the newer quantitative assessments. Gap-filling events have differed in size from those expected¹⁴⁻¹⁷, some observations suggest very irregular recurrence^{18,19} and many recurrence estimates critically depend on the assumed behaviour of plausible but idealized models^{8-13,20,21}. These difficulties raise questions concerning the degree to which long-term hazard can be quantified and the applicability of simple conceptual models to earthquake recurrence. To clarify these issues and the origins of observed recurrence behaviour, I have examined observations of repeated rupture of specific segments of subduction zones in the circum-Pacific region. These are summarized for the two most recent cycles of earthquake strain release in Fig. 1, and further details of these and earlier events are contained in refs 8, 14-17, 22-26.

An important feature of Fig. 1 is the complete absence of repeated events with similar source characteristics. Commonly, a single long rupture is succeeded by several gap-filling events in the next episode of earthquake strain release (Valparaíso, Colombia, Peru, Michoacán). Sometimes this involves encroachment of rupture into or from an adjacent segment (Southern Chile, Concepción). In several instances, not all of the plate boundary segment defined by preceding events has ruptured (Nankai and Kanto) and for several recent shocks (1979 Yakataga, 1986 Aleutians) only a small fraction of the seismic gap has yet been filled. Although the 1918 and 1963 Kurile earthquakes are generally similar, their mainshock epicentres are separated by 200 km.

A second notable feature of Fig. 1 is the timing, source size and magnitude pattern of gap-filling episodes that involve several events. These characteristics are summarized in Fig. 2, which shows that each event in the sequence invariably occurs in the last half of the seismic cycle, the majority being concentrated in the last 20% of the cycle. Furthermore, events show a strong tendency to increase in magnitude and rupture length toward the end of the cycle. The cycle duration in each region is defined by the largest events in the two most recent strain-release episodes. In four of the regions, times between the preceding great earthquakes are comparable to cycle durations defined in this way^{8,17,22}. For Peru the average interval is 194 yr for the past 2 cycles, for Concepción 98 yr (4 cycles), for Valparaíso 85 yr (4 cycles), and for Nankai 112 yr (4 cycles). In the three other regions (Colombia, Kanto, Michoacán), the seismic history is too poorly known to independently confirm my choice of cycle duration^{15,23,26}.

In many quantitative assessments of long-term risk the size of gap-filling events is not directly addressed and it is tacitly assumed that the expected earthquake will have the same features as the most recent preceding event. Previous studies have shown, however, that in several regions gaps have only been partially filled²⁷, events were smaller than expected¹⁴ or several shocks occurred when only a single event was anticipated¹⁵⁻¹⁷. The larger dataset shown in Fig. 1 shows that it has

THE WHITE HOUSE
WASHINGTON

October 12, 1989

MEMORANDUM FOR JOSEPH W. HAGIN, II
FROM: D. ALLAN BROMLEY *DAB*
SUBJECT: Proposed Meeting with President to Discuss
G-7 Science Ministers Meeting

John Sununu has suggested that I contact you to request fifteen minutes on the President's schedule on Monday, October 16 or Tuesday, October 17, for discussion of a possible meeting of the Science Ministers of the G-7 nations that I might host in March or April of next year. The purpose of this meeting would be to work toward an international program of research, drawing on the unique expertise and resources of the member countries to address gaps and uncertainties in our understanding of the science and underlying the entire spectrum of questions involved in the global environment. The goal would be that of evolving an international coordinated program of research comparable to the national U.S. program that the President made public at the Paris Summit meeting.

To the extent that we are successful in arriving at such an international research program on the global environment, it might constitute an agenda item for a subsequent Heads of State meeting at which the Heads of State might commit their respective nations and resources to participation in it.

I enclose a copy of a relevant earlier memorandum to the President, and a schedule proposal.

Attachments

cc: Governor Sununu

THE WHITE HOUSE
WASHINGTON

SCHEDULE PROPOSAL

October 12, 1989

TO: JOSEPH W. HAGIN, II
Deputy Assistant to the President
for Appointments and Scheduling

FROM: D. ALLAN BROMLEY *DAB*

REQUEST: To meet with the President.

PURPOSE: To discuss a possible meeting of the Science
Ministers of the G-7 nations in March or
April of 1990.

BACKGROUND: In followup to the President's announcement
in Paris of the U.S. national research
program on the global environment, the goal
of a meeting of G-7 Science Ministers would
be to evolve an international coordinated
program of research comparable to the U.S.
program.

PREVIOUS
PARTICIPATION: Follow-on to the President's environmental
initiative at the Paris Summit last July.

DATE AND TIME: Monday, October 16 or Tuesday, October 17

DURATION: 15 minutes.

LOCATION: The Oval Office

PARTICIPANTS: Governor Sununu, D. Allan Bromley

OUTLINE OF EVENT: Governor Sununu and Dr. Bromley arrive for
discussion with President.

REMARKS REQUIRED: None.

MEDIA COVERAGE: None.

RECOMMENDED BY: D. Allan Bromley

OPPOSED BY:

THE WHITE HOUSE

WASHINGTON

September 20, 1989

MEMORANDUM FOR THE PRESIDENT

FROM:

D. ALLAN BROMLEY 

SUBJECT:

HEAD OF STATE MEETING ON THE GLOBAL ENVIRONMENT

I know that you are currently considering how best to follow-up on your discussions at, and before, the Paris Economic Summit regarding a Head-of-State meeting focused on the global environment.

I recognize that you will necessarily weigh many factors in reaching your decision but want, in this memorandum, to make a few comments and a specific suggestion from my science and technology vantage point.

First, I believe that it would be a mistake to plan any such Head-of-State meeting too closely in time to the scheduled February 1990, IPCC meeting to be held here in Washington because the latter is rather focussed on global warming and this is only a part, albeit a highly public part, of the more general global environmental change question. Too close a coupling would, in my opinion, give undue emphasis to the global warming problem to the exclusion of others such as ocean pollution, biodiversity, and a whole host of other topics.

Second, I would argue that it would be important that the necessary preparatory work be done so that you would be in a position at the Head-of-State meeting to sign, with your fellow Heads of State, an agreement having very solid content.

To that end, I would propose - and have discussed very briefly with Governor Sununu - the possibility that in, say, April 1990, I host, here in Washington, a meeting of the Science Ministers or their equivalent from the seven nations involved in the Economic Summit in which we might try to agree upon a set of environmental change issues of international importance (including global warming, of course) and focus on the state of our current scientific knowledge of the phenomena underlying them. Having identified at least some of the most important gaps in such knowledge, we could then at least attempt to evolve a coherent, integrated plan, involving the scientific and technological communities of these seven nations, to address these gaps.

If we were successful, then such a plan might provide an appropriate environmental centerpiece upon which the Heads of State could formally agree and to which they might be prepared to commit their respective countries for action.

I make this suggestion, Mr. President, for the additional reason that it would allow you to maintain the strong leadership role that this country has earned and that you so effectively demonstrated at Paris.

... The possibility of including a broader spectrum of nations is one that I have rejected, not because they do not have essential contributions to make but rather to keep this initial discussion within manageable bounds. To the extent that we are successful initially we certainly would wish to spread our net rather early to include much broader representation.

I would welcome your guidance and comments.

10/18/89 16:59 202 252 0279

*DPC Working Group
on Global Change file*
ADMIN OFFICE EPA --- ENERGY DEP SEC

002



The Administrator
Washington, D.C. 20460

OCT 18 1989

*has been
updated
DA
10/26*

Admiral James D. Watkins USN (Ret)
Secretary
U.S. Department of Energy
Washington, D.C. 20585

Dear Jim,

I am enclosing the draft statement I would propose for the Hague meeting, as we discussed. After you have a moment to review it I would appreciate your thoughts.

Many thanks. (I've changed "CO₂" to "greenhouse gas emissions" as the object of a stabilization goal.)

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Reilly".

William K. Reilly

Copy received from Jim Watkins

DRAFT

Statement
William K. Reilly
Administrator, U.S. Environmental Protection Agency

Ministerial Conference
Atmospheric Pollution and Climatic Change

Noordwijk, The Netherlands
November 6, 1989

Mr./Mme. Chairman, Colleagues and Friends

The issue of global climate change forces us to look at our planet as an integral system. It also requires an integrated policy approach, for it is a scientific, energy, economic and foreign policy as well as environmental issue.

There is a growing consensus in the scientific community, that significant global warming due to man made greenhouse gas emissions is probable if current trends in these emissions continue . There are also significant uncertainties regarding both the magnitude and timing of warming and the implications of that warming for the climate system and environment.

The United States will substantially increase our budget for scientific research into the causes and consequences of climate change. President Bush has proposed a 43 percent increase in expenditures for answering critical scientific uncertainties related to climate change. Thus, we expect in the coming budget year to spend about \$192 million for this purpose. We are also making additional expenditures of about \$300 million on closely related global climate change issues.

Time, however, will not make the problem go away and we can not afford to wait until all the uncertainties have been resolved before we act. We need to provide insurance against the possible

adverse impacts from the greenhouse effect. We urgently need, as a first step, a Framework Convention on climate change to mobilize and rationalize the efforts made by the international community.

I take pleasure in announcing, on behalf of President Bush, that the United States would be willing to host a meeting of all interested nations to open negotiations on a framework convention, if this is the consensus following the next IPCC meeting this coming February in Washington. The meeting would be held in 1990 at a time convenient to interested parties and build on the work of the IPCC.

As was done by the world community in 1985, in starting with the framework Vienna Convention to initiate protection of the ozone layer, we think an agreement setting out general principles or guidelines is the way to start dealing with global climate change. In our judgement, whatever controls over greenhouse gas emissions are appropriate is a matter to be dealt with in specific protocols as has been done in the Montreal Protocol on CFCs which followed two years after the Vienna Convention.

The United States believes, however, that a goal of stabilizing greenhouse gas emissions should be seriously considered in this process. Each nation needs to take stock of its own situation and identify and assess measures for moving toward stabilizing greenhouse gas emission levels. We in the United

States are conducting this assessment.

The United States recognizes the special problems of developing countries in participating in the effort to address global environmental problems. We share their aspirations for better economic conditions. To this end we participate in and support a broad and evolving spectrum of bilateral and multilateral financial and technical assistance efforts -- many of which we helped initiate. We also recognize the need to reconcile the requirements for global economic development and a safe global environment.

Assistance is needed and will be provided. We have just launched a high level study on how to facilitate the transfer of environmental technology to countries that cannot afford to pay for it. We are also investigating the possibilities of debt for nature swaps and other innovative approaches.

We believe that the World Bank and other multilateral development banks have a particularly important role to play in promoting sustainable development, a role which we would expect to increase as the global community organizes itself to respond to climate change under a Framework Convention and supporting protocols. We strongly support the movement to have them incorporate environmental assessments into their decision making and to take account of the greenhouse effect when evaluating energy

and other projects.

In conclusion, we recognize that we are all in the same boat together with respect to global climate change. As President Bush said with respect to the problem of global warming in his recent address to the United Nations, "The United States will do its part;" but success will require the cooperation of all countries. Agreeing on a sound set of international responses is not a simple task; but we are committed to working towards this end building on the foundation of a Global Climate Convention.

Thank you very much.

THE WHITE HOUSE

WASHINGTON

October 23, 1989

MEMORANDUM FOR GOVERNOR SUNUNU

FROM: D. ALLAN BROMLEY, ASSISTANT TO THE
PRESIDENT FOR SCIENCE AND TECHNOLOGY, AND
CHAIRMAN, DPC WORKING GROUP ON GLOBAL
CHANGE

DAVID BATES, ASSISTANT TO THE PRESIDENT AND
SECRETARY TO THE CABINET

SUBJECT: Decision on the Hague Ministerial and
Related Issues

The DPC Working Group on Global Change met on Friday,
October 20 to discuss issues related to U.S. participation
in the upcoming Hague Environment Ministerial Conference,
November 6-7.

The attached is a discussion of the three issues for
decision. Please give us some guidance on how you would
like to proceed with this decision.

OPTIONS

1. The issues can be presented to the full DPC for
consideration and recommendations to the President.
2. The issues can be presented to the President in the
attached paper from us.
3. You can convene a small Cabinet group to make
recommendations to the President.

DECISION

Option 1 _____

Option 2 _____

Option 3 _____

October 23, 1989

ISSUE

I. Should the United States be represented at the Hague Ministerial Conference, November 6-7, at the ministerial level (EPA Administrator Bill Reilly) or at a lower observer level?

II. Should the United States offer to host the first negotiating session of a framework convention on global climate change, and if so, when should the President announce it?

BACKGROUND

The DPC Working Group on Global Climate Change, chaired by Dr. Allan Bromley, met on Friday, October 20 to discuss issues relating to U.S. participation in the upcoming Hague Ministerial.

The Netherlands will sponsor an international conference of Environment Ministers, November 6-7, to consider and to sign a declaration on global warming.

There is consensus among the relevant Federal Agencies and Departments that the United States cannot support the declaration because it is inconsistent with U.S. policy in several areas. It calls for action to stabilize carbon dioxide (CO₂) emissions by the year 2000 and to reduce CO₂ emissions by 20% by the year 2005, to reduce CFC emissions beyond the President's stated pledge, to create an international climate change fund, and possibly to create a permanent international secretariat to institutionalize the "Hague process" -- none of which can be supported by the United States, for obvious reasons, at the present time.

The Hague Ministerial also competes with a parallel process to address international global climate change under the United Nations Environment Programme (UNEP) -- the Intergovernmental Panel on Climate Change (IPCC). The United States was aggressive in advocating the creation of the IPCC and insisted on chairing the policy subcommittee (the Response Strategies Working Group) in order to consolidate the consideration of global warming into one international arena, in which we would have significant influence and control. We are, as a matter of policy, bound and committed to the IPCC process as the sole

international process for consideration of global warming issues.

For these reasons, the DPC Working Group agrees that the U.S. cannot support the draft Hague declaration and that there are significant risks for the U.S. to be represented at the ministerial level. It should be noted that EPA Administrator Reilly believes that a commitment for his participation was signaled to the Dutch Prime Minister in the presence of President Bush during the Dutch bilateral meeting, which followed the G-7 Paris Economic Summit. At that time, Administrator Reilly informed the Dutch that his attendance at the Hague Ministerial would be dependent on progress on the President's Clean Air Act proposal in Congress.

The DPC Working Group also discussed the related issue of a framework convention on climate change under the IPCC process. The issue of a framework convention has surfaced many times over the past year. At the first meeting of the U.S.-chaired Response Strategies Working Group (RSWG) in January, 1989, the United States successfully avoided the creation of a separate group to examine the issue of "legal instruments" or a framework convention. At the May RSWG meeting, after considerable press attention alleging that the United States was recalcitrant in moving forward on a framework convention, the United States invited countries to participate in a "workshop" to begin discussions of the elements of a framework convention. This workshop was held in Geneva on October 6, and discussion of a framework convention began.

It is now proposed by both EPA and the State Department that a decision be made, to be announced by the President, that the United States will host the first negotiating session of the framework convention after the final reports of the IPCC are completed.

This decision should be made within the context of the IPCC process and U.S. strategy in aggressively seeking its creation in 1988. The purpose in creating the IPCC was to avoid having to respond on many international fronts to the global warming issue, particularly in light of the scientific uncertainties. U.S. policy was to seek creation of a single global entity to address the issue. The IPCC was empowered to make a definitive international statement about the scientific analysis and uncertainties that currently exist, the actual effects of any global warming, and the potential policy options for responding. At U.S. urging, Great Britain became the Chair of the Science Working Group, the Soviet Union became the Chair of the Effects Working Group, and the United States became

the Chair of the Response Strategies Working Group. The Working Groups are to make reports, to be completed by the end of 1990, leading up to a World Climate Conference. At such time, after international consensus had been achieved, a decision on the need for a framework convention could be made on much more certain scientific and safer political grounds. Some in the Administration are concerned that if the United States does not offer now to host the first negotiating session, another country may issue the invitation and assume control of the process. It should be noted, however, that the Washington Representative for UNEP, representing the UNEP Director General, Dr. Mostafa Tolba, insists that the negotiations for a framework climate change convention will not be assigned to any country before Spring, 1990, and that the United States is the UNEP's preferred host for the framework convention, given the expected difficulty in negotiating any such convention. According to this UN official, any announcement for a negotiating session for the framework convention is premature, given the IPCC's current timetable.

The United States is currently functioning well within the IPCC. RSWG is meeting its obligations and is encountering little dissent. It should be noted, however, that RSWG is moving much faster than either the Science or the Effects Working Groups, on which the response policy was to have been based. So the process is somewhat inverted.

DISCUSSION

I. Should the United States be represented at the Hague Ministerial by its Environment Minister, EPA Administrator Reilly, or at a lower observer level?

PRO

A. Ministerial participation in the Hague Conference will show U.S. environmental leadership. Failure to participate at the ministerial level could be misconstrued as pulling back from commitments made at the G-7 Economic Summit.

B. The EPA Administrator could attempt to guide the Dutch declaration in a direction more consistent with U.S. and IPCC policy and could use the opportunity to stress the scientific uncertainties associated with global warming. Failure to send the EPA Administrator may represent a loss of U.S. influence in the "Hague process."

C. Failure to send the EPA Administrator may be misconstrued as lack of United States policy on global warming or unwillingness to articulate its policy in the international arena.

D. Failure to send the EPA Administrator may risk short-term political losses with the international and domestic environmental community.

CONS

A. The Hague declaration is antithetical to U.S. policy and our strategy in creating the IPCC.

B. If the EPA Administrator attends, he has no choice but to be negative toward both the substance and form of the meeting. The press and public perception will inevitably be that the United States opposes any progress on the global warming issue.

C. The EPA Administrator will be needed at the time of the Hague Ministerial to steer through Congress the President's most important domestic environmental initiative, the Clean Air Act. The EPA Administrator's absence at a crucial time in the Clean Air Act could cause significant domestic difficulties for the President. The risk of a double negative is high - international backlash for failure to support the Dutch declaration and domestic backlash for failure to be on-scene for the Clean Air Act negotiations.

D. The EPA Administrator's presence at the Hague Ministerial, regardless of the U.S. position on the declaration, may lend credibility to the concept of a permanent secretariat to institutionalize the "Hague process."

It was suggested that a graceful way to avoid many of the negative effects of failure to participate at the ministerial level would be for the President to send a letter to the Dutch Prime Minister making the following points: congratulating him on his leadership on the climate change issue; explaining U.S. policy and research goals for climate change; reiterating support for the IPCC process which we expect will eventually lead to the negotiation of a framework convention; and explaining that Mr. Reilly's presence is badly needed for a domestic Clean Air Act initiative which will be a model for the use of market mechanisms in service to environmental protection. Such a letter could be released prior to the Hague

Conference and would be the basis for the statement of the U.S. observer.

II. A) Should the United States offer to host the first negotiating session of a framework convention on climate change, B) and if so, should the President announce it before the Hague Ministerial or at a later date?

A. PROS

1. Hosting the first negotiating session on a framework climate change convention would place the United States in an international leadership role on the global warming issue. It would signal U.S. intention for international action, put the U.S. on the cutting edge of international environmental politics, and be popular with the domestic and international environmental community.
2. Hosting a U.S. negotiating session would allow the United States to have significant control and influence over the negotiating process and, possibly, the ultimate framework convention.
3. A U.S. decision to host the first negotiating session prior to the conclusion of the IPCC process, which is scheduled for November, 1990, would accelerate the IPCC process and would enhance U.S. influence within the IPCC.
4. A U.S. negotiating session would not be inconsistent with U.S. policy: the President made a statement in May, 1989 that he expects the outcome of IPCC to be the negotiation of a framework convention and the G-7 Paris Economic Summit communique advocates the negotiation of a framework convention.

CONS

1. The definition, form, and substance of the legal instrument for the framework convention is not yet determined. A decision to host a U.S. negotiating session assumes that the framework convention will not follow precedents for international legal instruments that we cannot support. We should know what kind of legal instrument is contemplated before the United States agrees to initiate the negotiation.
2. A decision to host a U.S. negotiating session assumes that the final IPCC report and international consensus will be consistent with U.S. policy, which is not at all certain at this time.

3. A decision to host a U.S. negotiating session will seriously reduce U.S. leverage to ensure that the IPCC deliberations are consistent with U.S. policy by prematurely supporting its conclusions, which will not be final until the end of 1990.

4. A decision to host a U.S. negotiating session undermines the reports of the IPCC Science Working Group, chaired by Great Britain, and the Effects Working Group, chaired by the Soviet Union, by suggesting that there is a need for a framework convention regardless of their conclusions. It distorts scientific analysis by presuming the scientific conclusions; in short, it places international politics before science.

B. PROS (Announce before the Hague Ministerial)

1. Announcement of a U.S. negotiating session prior to the Hague Ministerial Conference would ameliorate criticism for U.S. opposition to the Dutch declaration and, if Reilly does not attend, for failure to be represented at the Dutch conference at the ministerial level.

2. Announcement of a U.S. negotiating session prior to the Hague Ministerial Conference would preempt other countries from asserting a leadership role.

CONS

1. An announcement of a major environmental initiative, such as a U.S. negotiating session, should be tied to an important domestic event for a domestic audience for maximum domestic political benefit.

2. This announcement, should there be a consensus for a U.S. negotiating session, is more appropriate to the State of the Union, the February, 1990 Washington IPCC plenary session, or the President's International Conference on the Environment, should it be something other than the February IPCC.

3. Announcing a major U.S. initiative related to the IPCC prior to the Hague Ministerial would compound U.S. opposition to the Dutch declaration and the "Hague process." It could doubly embarrass the Dutch for the U.S. to announce a major initiative on a competing process shortly before their conference.