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Record Group/Collection:	George H.W. Bush Presidential Records
Collection/Office of Origin:	Science and Technology Policy, Office of (OSTP)
Series:	Bromley, D. Allan, Files
Subseries:	Global Climate Change Files - Conferences/Meetings
OA/ID Number:	62057
Folder ID Number:	62057-008

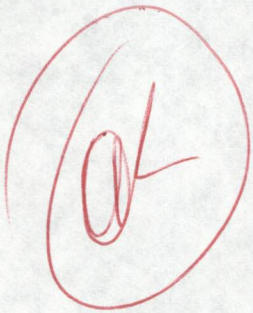
Folder Title:
Framework Convention on Climate Change (1) [1989-90]

Stack:	Row:	Section:	Shelf:	Position:
	0	0	0	0

1) Dr. Bromley

2) Marian

NOTE: Dr. White asked for an appointment...he is scheduled to see you on Thursday at 12:00 (not for lunch).



NATIONAL ACADEMY OF ENGINEERING

Robert M. White, President

10/18/89

TO: D. Allan Bromley

FROM: Robert M. White RMW

Attached is a copy of John Foster's remarks given at the NAE 25th Annual Meeting which we discussed last evening. I will discuss with you more in detail when I see you at 12 noon, Thursday, October 26.

"Marian" Show to Bromley and then use for background.

JJ

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10/26

Government Service: Developing a Climate for Change

By John S. Foster Jr.

National Academy of Engineering Founders Award

October 3, 1989
Washington, D.C.

Ladies and gentlemen:

I'm very pleased and deeply honored to accept this award. The Founders Award clearly ranks as one of the major highlights in my career. Frankly, I'm overwhelmed at being chosen to receive it. I thank the members of the Academy, and especially the members of the selection committee.

Seeing all these engineers and professors of engineering gathered here reminds me of that old story about a doctor, a lawyer, and an engineer who were captured in the desert and ordered to be executed by guillotine.

The doctor was led to the guillotine, placed face up so he could see the sharp, wicked looking steel blade. The blade dropped, stopping only two inches from his throat. Seeing this as divine intervention, his captors set him free. The very same thing happened to the lawyer: The blade stopped inches from his neck and he was pardoned. Finally, it was the engineer's turn. He was led to the guillotine, and as he was looking up to meet his fate, he said, "Hold it, I think I see the problem." Now, there's a dedicated engineer!

Throughout my career in the academic world, in government service, and in industry, I've had the privilege of working with some of the most talented, most experienced, and most dedicated people in the world -- truly the best and the brightest. I see this Founders Award as a recognition of their contribution as much as mine.

Reflecting on the people who have influenced my career, I thought about how men and women in and out of government have not only contributed to my effectiveness, but more important, how they've contributed to our nation ... People like Anne Armstrong, Norm Augustine, Harold Brown, Gene Fubini, Clare Luce, Rube Mettler, Dave Packard, Sam Phillips, Si Ramo, Edward Teller, Bud Wheelon, and many others. Most of these people have worked on both sides of the system -- in government service and in the private sector. I am, however, very concerned that this quality of service will be severely restricted, and our nation will be seriously crippled.

Thus, my purpose in the next few minutes is three fold: First, it is to convey to you the situation our nation is facing in attracting, retaining, and motivating the best people in government service; second, it is to convince you of the great sense of urgency to address and redress the situation; and third, it is to put forward the proposition that the NAE and its sister organizations, the National Academy of Science and the Institute of Medicine, must do their part to initiate a set of actions to bring about the necessary changes to revitalize federal service and improve the effectiveness of our goverment.

These great organizations, NAE, NAS, and the IOM, were established to respond effectively to both the disciplinary concerns of the research community and the interdisciplinary problems facing American society. The instant issue is whether our government has what it takes to do something constructive with our past and current recommendations, or whether the "human resources erosion" we are experiencing among the government's three million-member work force has crippled our nation's ability to make meaningful decisions about programs vital to our future. So, my challenge to you, as scientists, as engineers, as medical doctors, as academicians, and as concerned Americans is to help cause our government to work the way it's supposed to work.

Our government plays many vital roles in nearly every aspect of our lives -- from providing for our national security, negotiating and verifying arms control agreements, and providing much needed services, such as education, Social Security, and ensuring the safety of our automobiles and airplanes. In addition, we must depend on our government to provide policy leadership and resources to tackle

such problems as drugs, AIDS, terrorism and the decay of our global environment.

The nature of the problems confronting our nation and our ability to deal with them has changed dramatically in the last few decades. The problems are more complex and our flexibility to deal with them is more restricted. Nuclear waste disposal, for example, turns out to be much harder to deal with than was the development of nuclear reactors a few decades ago. The same is true of our environment and possible global warming, which is more difficult to solve than discovering oil and natural gas.

Paul Volcker perhaps put it best when he said (and I quote) "For all the glories of Adam Smith, somebody has to set the rules and adjudicate disputes. Somebody has to defend the country and to explore space. Somebody has to keep the air clean and the environment safe for the next generation. Somebody has to respond to those more mundane, but nonetheless quite challenging, assignments of keeping government working effectively and efficiently if self government is to work at all." (unquote)

And, we must expect our government to do all this according to the highest standards of ethics and conduct. What's clear is that the government is no place for amateurs; we should expect no less than our very best people and the highest degree of professionalism in government service.

Given that awesome task, what is the public's perception of our government? The Volcker Commission report says the public is very dissatisfied with its civil servants. The report says, (and I quote) "The public believes that the public servant is less productive and enjoys more benefits that his or her counterparts in business." (unquote) When it comes to Congress, public opinion polls regularly lambast (quote) "the mess in Washington" and decry Congressional inaction. The public regularly makes jokes like this one: What do Bally Shoes and the government have in common? Answer: they both have a half a million loafers! And that's one of the milder things people say about their government!

There are, of course, plenty of examples to support such harsh assessments. Just look around. We have crippled nuclear weapons plants, savings and loans failing, and defense contract scandals, to name just a few.

Perhaps the worst problem, and one of the root causes for our current difficulties, is the dismal state of our educational system. The leadership for education must come from federal and state government. It's impossible to imagine that this great country, which was built on its commitment to excellence in education and the application of science and technology to achieve unparalleled prosperity and economic competitiveness, has allowed its educational system to sink to its present levels of inefficiency and ineffectiveness. Unless something is done with federal and state leadership, we're headed for a time when other nations will lead in the development and application of science, engineering, and medicine and our own nation will atrophy.

Of course humans, even the best of them, aren't perfect by any means. And that's understandable. With three million civilian and military people in the government work force, there are thousands of important decisions and actions taken every working day. A very small percentage of these will turn out to be wrong. It is important that our system be able to detect these errors and correct the situation sooner rather than later.

When these lapses in judgment are selected by the news media for special attention, it can be painful, but if the reporting is accurate, there is little cause for complaint. To my mind, however, the most serious damage to government is done when the highlighting of "horror" cases involving a very tiny fraction of government employees, leads the public to conclude that our government consists of incompetent, self-serving bureaucrats who don't deserve their pay or our support. In turn, this negative public attitude leads to fewer good people entering public service for their life's work and that leads to a less capable government and the public and the country are worse off.

The report of the Volcker Commission makes it clear that we have a complicated mess on our hands and that no single set of actions by the executive or legislative branches or by the private sector will quickly redress the decline. It requires that we start doing a lot of things right in many different places. Since this is too large a scope to deal with at the moment, let me focus on the attraction, retention, and development of the best professionals for the Executive Branch of government.

The Executive Branch relies on two types of people. One type are those who enter government service expecting to make it a lifetime career. These career civil servants make up the bulk of the personnel in the Executive Branch. As their careers develop, these people may end up running hospitals, national laboratories, commanding military forces, or managing multi-billion dollar space and defense programs. Clearly, we must have the highest quality professionals managing these kinds of critical activities.

The problem is that we don't pay or support these career civil servants anywhere near the way we should. For example, a senior-level government engineer, a GS-15, currently earning $71,000 a year, would make over $85,000 annually working in the private sector. Money, of course, should be secondary in any consideration of government service. The high calling, the challenge of the job, the opportunity to serve your country, and the chance to make a difference should be paramount. But, because the pay gap has become unnecessarily large, our most promising young scientists and engineers are choosing the private sector over civil service careers, where they would be paid significantly below their true market value.

The second group of people go into government intending to serve only a few years in senior positions in the Executive Branch. These people are attracted to government because they have achieved excellence in their careers and their excellence is needed by the government. They usually stay perhaps five to 10 years and then return to the private sector. Political appointees generally stay shorter periods, making it very difficult for them to function to their full potential. However, I believe this rotation of people from private sector into government and back is a good thing for the country and a good thing for those people -- it's the "revolving door" put to its best use. Government service is a high calling, one that should attract more of our best citizens. If we acquire the best professionals in the top positions, it makes it much easier to attract, motivate and retain the best people in middle and senior level positions.

Over the last two decades, however, we've managed to make it increasingly difficult to attract professional people to serve in Presidential appointee positions. Let me sketch for you a picture of an executive who's received a call to serve his country. The

executive in question may be another Norm Augustine, Harold Brown, Bud Wheelon, or any one of you here today.

The person I have in mind is, say, 40 years old. He's a vice president of research and engineering for a large industrial company. He's married and has two college-age children. He earns about $200,000 a year and enjoys all the normal executive perks: stock options, a well funded retirement plan, an excellent benefits package, and so on. Our executive has been asked to serve as an Assistant Secretary for research and development, a job that pays about $80,000 a year.

If our executive decides to accept the job, conflict-of-interest laws require him to sell his stock and buy out of his pension plan, actions that will undoubtedly cost him hundreds of thousands of dollars. He'll have to foot his own moving expenses, since the government won't pay them and federal gratuities rules forbid his company from paying them.

Finances aside, our executive, who's held positions of trust and responsibility for the last 20 years, must face microscopic Congressional and public scrutiny. His personal and professional life, and the lives of his wife and children, will become an open book to inquiring Congressmen and probing news media. Past investments, family illnesses, even "revelations" that one of his kids cheated on a high school algebra exam are likely to make the evening news.

The hiring of Presidential appointees raises two important issues. First, the confirmation process is now taking much too long to complete. Lengthy investigations, hearings that drag on for weeks, and interminable delays have all but crippled the government's ability to bring such people on board in a timely manner -- further discouraging prospective employees from serving.

Second, complex and confusing ethics rules are penalizing the many good people who wish to serve their country. Certainly we want honest men and women in government, but we've now reached a point where Congress is asking questions your mother wouldn't ask about the most intimate details of your life and then making those disclosures public. To my way of thinking, it's simply not civilized.

Don't get me wrong, Federal regulations to prevent wrongdoing in industry and government are vital to protecting the interest of the government and the American taxpayers. But stringent revolving door policies and Draconian rules governing conflict of interest have made government service akin to navigating through a minefield. It all boils down to maintaining perspective -- an element that's badly lacking in today's "hang-the-bastards" mentality emanating from Washington.

If our executive does serve, he'll work harder than he's ever worked in his life -- with some of the most dedicated and talented people he'll ever meet. But he'll be micro-managed by Congress and second-guessed by the news media and the public every step of the way. He'll take the heat for any bad decision, and get little or no credit for all the good decisions he makes. His political loyalties will be tested and re-tested. In short, he'll be put in a political straight-jacket that will often force him to act on behalf of narrow party interests rather than in the best interests of the nation.

Because of blatant political partisanship, cabinet officers don't usually get to choose their own team; they're selected on the basis of party support. We've seen the embarrassment, which result from media stories about some ambassadorial appointees, whose main credentials are the right friendships and campaign contributions. What's needed is loyalty to the mission and professional competence over loyalty to the party in power. That's especially true in such non-political areas as medicine, science, and engineering.

Finally, after putting in four hectic years, years which Norm Augustine called (and I quote) "the most exciting, challenging, and demanding experiences of my life," (unquote), our executive will want to return to his company and resume his career. Now, 45 or so, he'll be in an excellent position to become an executive vice president or even a CEO.

But recently enacted federal procurement regulations forbid his company from hiring him back in his old job for two years. So for now, our executive's career is on hold. Of course, he can go back to a lower level job and wait it out. Or, he can go to another company in a completely different position. Either way, his career may have been dealt a death blow -- all because he decided to answer the call of

government service. In essence, we have created major "post-operative" problems for people leaving government service. These problems, in turn, make Federal employment even more unattractive, especially to senior-level professionals.

Jim Woolsey, who served as Under Secretary of the Navy and now is a distinguished Washington lawyer, has written that the problem with current ethics laws is that they are written by and are best applied to lawyers, who specialize in understanding the nuances in the law, and are not realistic in their broader application. The situation facing scientists and technical people is different in that these people are normally experts on substance, not procedure. Their knowledge pertains to such fields as immunology, materials science, acoustic signal processing, and so on. When these technical people leave government service, writes Woolsey, (quote) "the whole nature of their professions requires them to interact with colleagues on these substantive issues. Their substantive knowledge, unlike lawyers', is essentially a seamless web." (unquote)

And so, one can imagine an ad for government executive service that reads like this:

> "Wanted: Senior level business executive willing to take the last test of devotion. The challenge is to execute programs designed and managed by Congress. Must have strong masochistic streak. Must thrive on poor working conditions; relish abuse, tolerate libelous public exposure, and intimidation is guaranteed. Rhinoceros skin preferred and ability to work with difficult people vital. Termination of government employment will require pursuit of a different career. For this ego trip, family must accept major pay cut and divestiture of industrial holdings.
>
> Send resume to the junior administrative assistant of the special assistant to the deputy under-secretary of the Office of Personnel.

Seriously, the low prestige afforded government employees has done a tremendous disservice to our nation. The much-heralded bureaucracy bashing of recent administrations has undermined public confidence in government agencies and eroded the morale of existing government employees. Decision makers, eager to avoid

grief from Congress, the public, and the media, often forego making tough decisions altogether. Such gun-shyness then leads to new attacks on "do-nothing" bureaucrats who waste the taxpayers' money, thereby creating a vicious circle of inaction, criticism, and more inaction. The result, of course, is that little of any real value gets done.

Gone are the days of the "dollar-a-year men," those tough-minded company executives who stayed on company payrolls while earning a dollar a year keeping the wheels of government turning during the dark days of World War II. Who would have cried conflict of interest then? Who would have questioned their patriotism in any way as they oversaw the buildup of our armed forces that led us toward victory? I fear those days may be gone for good.

Let me give you a few real-life statistics on the problem of finding and keeping qualified career civil servants and Presidential appointees:

-- The National Institutes of Health, one of the world's premier medical research organizations, has lost 28 percent of its senior research scientists in the last 10 years, the vast majority of them to the private sector.

-- NASA recently lost nearly 200 managers and scientists, including 34 members of the Senior Executive Service. Most of these people left the space agency for higher salaries or were escaping the new restrictions being imposed on post-government employment. The rules impose gag-like restrictions on who government employees can talk and cannot talk to in the scientific community when considering procurement decisions. One NASA scientist summed up the situation by saying, (and I quote) "The reason I've stopped talking is because I don't want to go to jail." (unquote)

-- In the Executive Branch, President Bush has been unable to place 45 percent of his appointees in top government jobs because of political wrangling, low salaries, new conflict of interest rules, and increased public scrutiny of the nominees' private lives. Of the several hundred people approached for senior jobs in the Bush Administration, 40 have refused service on financial grounds alone. The financial hardship was simply too great.

-- The future for government service looks equally grim. Derek Bok, president of Harvard University, has written that of the 10 percent of all college seniors earning 3.5 grade, or B plus averages, only 2 percent enter public service. And, among college seniors belonging to honor societies, less than 5 percent will even consider a government career.

The federal government's inability to attract, motivate and retain, the kinds of people we need to do work that's essential to our nation cuts across all levels of government employees -- from senior officials in the Pentagon to those who sweep floors of the Capitol building. The jobs affected include everything from designing advanced defense systems and managing multi-billion dollar space programs to collecting taxes, reforming our educational system, and keeping tabs on Social Security checks.

Even America's international competitiveness can be tied to the government service. Government jobs do not enjoy the same status and respect in the United States as civil service positions in other countries. In Japan, for instance, graduates of the University of Tokyo fight tooth and nail for positions in various government ministries. In France, top students regularly enter fast-track government careers. And in Britain, honors graduates from Oxford and Cambridge see government service as a rewarding and satisfying career. It's no wonder, then, that America is outmatched and outgunned when it comes to negotiating international issues!

Let's face it, when it comes to attracting good people to serve, the government is in head-to-head competition with the private sector, and the government is not sufficiently competitive. Think about it. The government is trying to attract only 3 percent of the total work force. And, it's becoming less competitive all the time.

So now that brings me to the hardest part -- what to do about the problem. The Volcker Commission and others have studied the issue of government ineffectiveness. Out of these studies have come numerous well supported recommendations for the Executive Branch, Congress, and the media. In short, much work has been done, and there is yet no mandate for change.

All Americans should regard inaction as simply unacceptable.

Many discouraged people both in and out of government believe that things will have to get worse before they get better. Now what does that mean? I guess it means that at this time there is no consensus for change. But, as Machiavelli once observed, "Change has no constituency." Yes, it takes leadership. But at this time, the job of leadership is to take those actions which begin to create the climate for change. And then to build the constituency for change. Only then can our leaders initiate the actions that will be implemented to solve the problems and make government work the way it must work if America is to succeed and prosper.

The situation is far from hopeless. In fact, you can see definite signs of improvement:

-- President Bush has upgraded the status of his science advisor. He has attracted an outstanding scientist and administrator, Dr. Alan Bromley, and has made him a member of the senior councils, with direct access to and support of the President. Dr. Bromley, in turn, is in the process of filling four associate director positions, which shouldn't be difficult, given the improved status and Dr. Bromley's obvious talent. As the saying goes, "Talent attracts talent."

-- President Bush also is taking actions to improve conditions for Federal employees, through his Federal pay-raise plan and through recent speeches praising our nation's civil servants. these efforts are a definite step in the right direction.

-- The President directed the Secretary of Defense to develop "a plan to improve the defense procurement process and management of the Pentagon." In particular, he called upon the DOD accomplish full implementation of the recommendations of the Packard Commission. And those efforts are underway.

-- The President, in his efforts to stem the flow and use of illegal drugs, to upgrade the nation's space program, and to improve our educational system, is setting a personal example of what highly motivated government employees can can do to make a difference. President Bush's meeting last week with our nation's governors for the first "education summit" was especially encouraging.

It's evident that the President is doing his part to make the public realize that he and his Administration are working for the good of the people. And, with a growing confidence in the Executive Branch, we begin to improve the climate for change. Given the President's mandate for action, Congress, business, and the academic community must do their part to bring about change.

Congress must remove the over-burdening checks and balances it has established for the Executive Branch so that public servants can feel like they have the opportunity and authority to accomplish something. A common standard should be set for all three branches of government. Our lawmakers must work to improve the pay structure to bring Federal salaries closer in line with the private sector. Congress should define reasonable requirements for a blind trust for people like our hypothetical business executive who have to give up their stocks and pension plans. And, it should provide better incentives for those already engaged in government service. The goal should be not only to recruit professionals but also to develop and retain professionals within the government's ranks.

Our three branches of government constantly receive demands to establish policies, practices, and laws to prevent bad things from happening. Frequently, in attempting to prohibit isolated incidents, additional burdens and barriers are imposed on the whole. More often, it seems to me, people in all three branches of government should stand back and ask, "would such a practice, policy or law really help the country?" And when the answer is "No", have the dedication and courage to work the details to see that whatever action is taken leaves the country better off, not worse.

Those in the academic community must be more supportive of people who choose government service, either as a career or on an appointive basis. Those in industry must do their part by acting more responsibly in controlling program costs and in working more closely with Congress and the news media to improve their image and that of their customer.

That brings me to you, members of the National Academy of Engineering, the National Academy of Science, and the Institute of Medicine. What can we do to help bring about the necessary changes? We must realize that the effectiveness of NAE, NAS, and the IOM are dependent on the effectiveness of the Legislative and Executive branches of government when it comes to their

consideration and implementation of the recommendations we make on science and technology policies and programs. Therefore, we must assure ourselves of the effectiveness of government as a part of our advice and counsel to government.

My proposition is that the NAE, the NAS, and the IOM develop a specific set of recommendations to the President of the United States to redress this situation. Each should develop a set activities that would represent our best efforts at assessing and improving the current state of American science, engineering, medicine, and education, by examining the talent and trends in government and developing inducements for attracting, training and retaining the best people to serve our country.

Changing long-standing attitudes and trends is damn difficult, but it's vital to America's future. That's why I urge these bodies, as a matter of paramount importance, to heed the words of Rube Mettler and "accept the burden of initiative."

Let's hope that at future annual meetings of the Academies we'll have a fresh supply of outstanding people who've heeded their country's call. And, again, thank you for this wonderful honor.

# # #

THE CHAIRMAN OF THE
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON

December 13, 1989

MEMORANDUM FOR D. ALLAN BROMLEY

FROM: MICHAEL J. BOSKIN MJB

SUBJECT: U.S. Position on Climate Change Convention

I have recently had some disturbing conversations about the ongoing international discussions aimed at the development of a framework climate change convention and subsequent protocols, as well as the position that U.S. representatives have taken in those discussions. I am writing to let you know that it is imperative that a major shift in our position be made.

The U.S. has apparently not challenged the view (which is reflected in Fred Bernthal's memo to you of October 24 and, even more clearly, in the legal and institutional measures portions of the October RSWG Workshop draft report now being circulated for comment by EPA) that the convention should be drafted in anticipation of a large number of gas-specific and policy-specific follow-on protocols. This many-protocol approach ignores important regulatory lessons that have been painfully learned in the U.S.; it would place us and the world as a whole on a path toward unending negotiation and detailed regulation that would be both ineffective and expensive. <u>This approach is philosophically inconsistent with the President's approach to regulation in general and with his stated position on the need to reconcile the environment and economic growth.</u>

A far superior approach, which the U.S. should adopt forthwith, would be to draft the convention in anticipation of negotiating only country-specific limits on total net greenhouse emissions (or, more plausibly, a formula for computing those limits), along with protocols on baselines, funding mechanisms, enforcement, research, monitoring, technology transfer, and related implementation issues. This approach, which explicitly rules out gas-specific protocols and international agreements on specific control measures, would allow each country to find the best way to reduce its impact on global climate, taking into account its own economic, political, national security, and lifestyle conditions and concerns. Most nations, we should hope, would adopt flexible, incentive-based approaches, but those who choose to rely on other methods would be free to do so. All the world as a whole legitimately cares about is the change in the global atmosphere, not the method by which the U.S. or any other nation makes its contribution to that change.

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The many-protocol approach would lead us instead to attempt to replicate on a world scale the sort of detailed command and control regulation (epitomized by scrubbers on powerplants) that we have tried and found wanting in the U.S. The inflexibility that would be induced by a large number of specific protocols would dramatically raise the costs of whatever actions were ultimately taken to mitigate global change. (We should also reconsider the need for multilateral protocols on adaptation, which are now envisioned, since, research and technology transfer aside, the adaptation measures that have been widely discussed have at most regional effects.)

The many-protocol approach may be a recipe for inaction. Strong actions to control emissions of any particular greenhouse gas or operation of any particular source category would impose very different costs on different nations. We might be willing to take drastic steps to reduce methane emissions from our rice paddies, for instance, but it is hard to imagine much enthusiasm in East Asia. If those nations don't go along with a strong rice paddies protocol, however, methane emissions from rice cultivation will not be noticeably decreased, even if such decreases would represent the most cost-effective way for East Asia to reduce its net greenhouse emissions. Bundling issues (gasses, sources, and sinks) makes an effective agreement to control net emissions more likely.

At the same time, the many-protocol approach may be a recipe for singling out the U.S. and other advanced nations for disproportionate burdens, since we might well find it hardest politically to resist any proposed protocols. Under this scenario, the first protocol would call for the equivalent of 50 m.p.g. CAFE standards for all new cars, the second would set absurd efficiency standards for home appliances, and so on. We could easily find ourselves nibbled to death by a large number of protocols aimed at rich nations but having, in aggregate, little effect on ambient greenhouse gas concentrations.

I thus consider it vitally important that the U.S. firmly and quickly reject the many-protocol approach in the IPCC process. That approach is inconsistent with the President's stated view, which is solidly grounded in U.S. experience, that flexible and incentive-based regulation best harmonizes environmental concerns with economic growth, and is particularly unlikely to produce sound policy in this multi-national setting.

On the other hand, I do not mean to suggest that a crusade on your part will be necessary to bring this about. Last week Boyden Gray met with representatives of EPA, State, Justice, CEA, and other interested parties, and he made the case for a position shift of the sort I have described. There was no visible resistance, so that this shift may occur without your participation. On the other hand, appearances can be deceptive,

and meditation may produce opposition. I thus urge you, if the occasion arises, to support movement away from the many-protocol approach to drafting a climate change convention and to a simpler and more rational approach based on changes in what matters: net greenhouse emissions.

I would, of course, be most interested in your reactions to all this.

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01a. Memorandum	To: Timothy Deal From: Allan Bromley Re: Paper of G-7 Sherpas (2 pp.)	6/8/90	(b)(1)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: Global Climate Change Files - Conferences/Meetings
WHORM Cat.:
File Location: Framework Convention on Climate Change (1) [1989-90]

Date Closed:	4/20/2010	**OA/ID Number:**	62057-008
FOIA/SYS Case #:	2005-0336-F	**Appeal Case #:**	
Re-review Case #:		**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
AR Case #:		**MR Case #:**	
AR Disposition:		**MR Disposition:**	
AR Disposition Date:		**MR Disposition Date:**	

RESTRICTION CODES

Presidential Records Act - [44 U.S.C. 2204(a)]

P-1 National Security Classified Information [(a)(1) of the PRA]
P-2 Relating to the appointment to Federal office [(a)(2) of the PRA]
P-3 Release would violate a Federal statute [(a)(3) of the PRA]
P-4 Release would disclose trade secrets or confidential commercial or financial information [(a)(4) of the PRA]
P-5 Release would disclose confidential advice between the President and his advisors, or between such advisors [a)(5) of the PRA]
P-6 Release would constitute a clearly unwarranted invasion of personal privacy [(a)(6) of the PRA]

C. Closed in accordance with restrictions contained in donor's deed of gift.

PRM. Removed as a personal record misfile.

Freedom of Information Act - [5 U.S.C. 552(b)]

(b)(1) National security classified information [(b)(1) of the FOIA]
(b)(2) Release would disclose internal personnel rules and practices of an agency [(b)(2) of the FOIA]
(b)(3) Release would violate a Federal statute [(b)(3) of the FOIA]
(b)(4) Release would disclose trade secrets or confidential or financial information [(b)(4) of the FOIA]
(b)(6) Release would constitute a clearly unwarranted invasion of personal privacy [(b)(6) of the FOIA]
(b)(7) Release would disclose information compiled for law enforcement purposes [(b)(7) of the FOIA]
(b)(8) Release would disclose information concerning the regulation of financial institutions [(b)(8) of the FOIA]
(b)(9) Release would disclose geological or geophysical information

CLOSE HOLD

Document No. _____

WHITE HOUSE STAFFING MEMORANDUM

DATE: 6-6-90 ACTION/CONCURRENCE/COMMENT DUE BY: NOON, Friday June 8

SUBJECT: Consensus Paper prepared by G-7 Sherpas for Economic Summit

	ACTION	FYI		ACTION	FYI
VICE PRESIDENT	☐	☑	MCCLURE	☐	☐
SUNUNU	☑	☐	NEWMAN	☐	☐
SCOWCROFT	☐	☑	PORTER	☑	☐
DARMAN	☑	☐	ROGICH	☐	☐
CARD	☐	☑	UNTERMEYER	☐	☐
CICCONI	☐	☑	BOSKIN	☑	☐
DEMAREST	☐	☐	BROMLEY	☑	☐
FITZWATER	☐	☐	DELAND	☑	☐
GRAY	☑	☐	_____	☐	☐
HAGIN	☐	☐	_____	☐	☐
HOLIDAY	☐	☐	_____	☐	☐

REMARKS: The attached was developed by the G-7 Summit Sherpas, and will will sent forward to counterparts shortly. Please forward any comments to Tim Deal, NSC (X 3622) by noon, Friday June 8 with a copy to this office. Please note section on environment.

JWC

RESPONSE:

James W. Cicconi
Assistant to the President
and Deputy to the Chief of Staff
Ext. 2702

CLOSE HOLD

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01b. Paper	Consensus paper prepared by G-7 Sherpas for Houston Economic Summit (16 pp.)	6/6/90	(b)(1)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: Global Climate Change Files - Conferences/Meetings
WHORM Cat.:
File Location: Framework Convention on Climate Change (1) [1989-90]

Date Closed:	4/20/2010	**OA/ID Number:**	62057-008
FOIA/SYS Case #:	2005-0336-F	**Appeal Case #:**	
Re-review Case #:		**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
AR Case #:		**MR Case #:**	
AR Disposition:		**MR Disposition:**	
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Presidential Records Act - [44 U.S.C. 2204(a)]

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P-4 Release would disclose trade secrets or confidential commercial or financial information [(a)(4) of the PRA]
P-5 Release would disclose confidential advice between the President and his advisors, or between such advisors [a)(5) of the PRA]
P-6 Release would constitute a clearly unwarranted invasion of personal privacy [(a)(6) of the PRA]

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THE WHITE HOUSE

WASHINGTON

June 14, 1990

MEMORANDUM FOR JOHN H. SUNUNU

FROM: D. ALLAN BROMLEY

SUBJECT: SEA LEVEL CHANGE AND ENVIRONMENTAL MATTERS

Like all else in the global warming arena the calculation of sea level change is much more complicated than it appears. First some general comments:

1. Assuming for the moment a rise in atmospheric temperature there are two determining constants at work. First is that at the atmosphere-ocean interface, i.e., how much thermal energy is transferred to the water and at what rate? Second is that of the internal ocean transport mechanisms that carry this thermal energy into the bulk ocean.

2. Considering the Atlantic, as an example, thermal energy transferred to the Gulf Stream is carried northward and in the Greenland-Iceland region it splits with something like 90 percent remaining on the surface and continuing its clockwise surface circulation. This involves the upper 100-200 meters at most. The remainder (about 10%) is carried downward and flows again southward at much greater depth. What this means is that the thermal expansion of the ocean from the bulk of the ocean--depths greater than 100-200 meters-- is delayed by something between 50 and 100 years as compared to that of this 100-200 meter surface layer.

3. It is important to note that for salinity greater than 24.7 permil, the density of sea water increases with decreasing temperature all the way to the freezing point, i.e., there is no maximum in the liquid density vs temperature plot as is the case with fresh water. Also counterintuitively, the coefficient of thermal expansion of sea water increases with increasing pressure i.e., depth.

4. The simple minded expansion calculation--in zeroth order follows from the hydrostatic equation

$p = \rho g h$ where p = pressure, ρ = density
g = acceleration due to gravity
h = depth

and $a = \frac{-1}{\rho}\frac{d\rho}{dT}$ where T is the temperature and
a is the thermal expansion coefficient

5. As water expands the sea levels rises but $\partial p = 0$

$\partial p = \partial \rho g h + \rho g \partial h = 0$ so

$a g h \partial T = \rho \partial h$ and $\partial h / \partial T = a h$

Here in the zeroth order we simply take an average depth <h> ~3800 m on the assumption (wrong!) of complete thermal equilibrium and set

a (T, p, s) ~ (10 to 20) x10^{-3}/C where s is the salinity, and so find

$\partial h / \partial T \sim 60 cm / {}^{o}C$

6. From this we see that a 0.10C rise in temperature corresponds to 6 cm sea level rise as indeed would a 0.4 C rise in the top 1000m and no temperature change in the lower levels. But this is a very crude model.

7. In the IPCC WG 1 report that predicts an effective CO2 doubling by 2030, the predicted sea level rise is 18cm. This is composed of the following contributions

(a) Thermal expansion--10 cm. The report discusses in some detail an up-to-date box diffusion model that does take into account the variations of salinity and of temperature. The authors of this particular section of the report are publishing a book later this year on their calculation and perhaps reflecting that, their discussions in the IPCC report are not as clear as they might be in places. Indeed one could (as I did) read the policymaker's summary as suggesting that the 10 cm figure came from a linear extrapolation of historical data on sea levels to the 2030 temperature predicted by the GCM models. I find however that the more complex box model calculations were actually used.

(b) Melting of land based glacier ice--7 cm. Here I am quite confident that this number results from simple linear extrapolation of the recent historical data on the retreat of mountain glaciers.

> Note: Such extrapolations are on shaky grounds. The association of past historical behavior with the atmospheric temperature--on a single parameter basis--has very little justification. Similarly, there is little justification for linear extrapolations. The global circulation models give static, point-in-time predictions but no insight into the path from one of these states to the next. The historical record suggests substantial fluctuations about any average. Finally, my earlier memo on the carbon cycle raises its own questions regarding the assumption of effective doubling in 2030.

(c) Melting of the Greenland ice cap--2 cm. All GCM's predict that polar regions will experience greater greenhouse warming than equatorial ones in any warming scenario.

(d) Sequestering of water in Antarctica--(-l) cm. Because of its much greater area and predicated increased snowfall it is anticipated that Antarctica will actually

sequester water in a warming scenario. It bears noting that melting of 0.1% of the Antarctic ice corresponds roughly to a 1 meter change in global sea level.

Adding up all these contributions then leads to the quoted 18 cm prediction for sea level rise in 2030.

What we really need is a solid scientific look at this entire question, recognizing that it is difficult and that many of our input data are fuzzy. I am hoping to interest NOAA and NSF in doing such a study. We can do better!

I share your concern, and Dick Darman's, that by focussing on the anthropogenic greenhouse gas sources and sinks in the policymaker's summary--and the executive summary--and by omitting much mention of the 20 times greater natural fluxes, the authors end up with a distorted perspective even though both anthropogenic and natural fluxes are treated quite well in the body of the main report--which relatively few people will ever read!

I am also concerned that if we appear to accept IPCC WG 1 as ultimate truth then to some extent we have been effectively coopted into accepting the recommendations of the IPCC WG 2 and 3 which may well be substantially different from what we had in mind.

Let me turn then to a different topic.

The June 8 UNEP and RSWG (IPCC WG 3) meetings in Geneva, in my opinion, were particularly important in demonstrating that we are increasingly seen as occupying a centrist position with the EC (Netherlands, FRG, etc.) as the extremists. It will be important for us to continue fostering this view as more and more nations begin to recognize that they were overly hasty and even emotional in their willingness to sign up for targets and timetables last November in Noordwijk. Sanity<u>is</u> returning slowly to this field!

I believe that the President's leadership in this entire global change area is increasingly being recognized--albeit reluctantly in some communities--and that by injecting economics directly into the discussions at the White House Conference we have achieved much more than the international press was prepared to admit at the time.

It will be very important for us to develop our positions in the entire global change and environmental areas as soon as possible because in the face of the rather ridiculous number of conferences, workshops, ministerials, etc., upcoming, in the absence of such firm and generally agreed upon positions, we tend to get ratcheted toward positions that are not in our best interests.

Your suggestions and comments would be most welcome.

6/13/90

Dr. Bromley:

On the memo on sea level rise, I have a couple of specific comments.

a. The 90%/10% split on Gulf Stream surface and deeper water may not be correct - I would not use percentages. It would be better to say most of the water stays on the surface while a small percentage is carried down...

b. I checked with Watson and he said that while Tom Spence's analysis might be right that the text of the Policymaker's Summary may (incorrectly) imply that the thermal expansion of the ocean was derived from extrapolation from historical data, he doublechecked and, indeed, the thermal expansion numbers are the result of the most up-to-date box diffusion model which takes special account of the salinity and temperature changes under such conditions. In fact, the two main authors (modelers) of this section are writing a major book on sea level rise which would be out now except that they have been spending all of their time on the IPCC report over the past year.

I have attached pertinent pages of the IPCC Chapter on Sea Level Rise - I have clipped several pages which describe the model.

c. While I agree with what you have said on page 5 about better science needed on the issue, (and I do recognize the theological constraints under which you are operating here) I think that we may want to go easy on the IPCC report and, at the same time, call for better science on the subject.

How about something like the following instead of the paragraph marked "C":

While the authors have worked hard to provide predictions based on what scientific information is available at this time, it is obvious that we really need better and more solid scientific analysis at the entire question. In fact,I am hoping to interest NOAA and NSF in doing such a study. So that we are not PERCEIVED as backing away from the President's (and other Administration) previous statements on the IPCC report, we should probably publically respond to the IPCC report as a good first start at summarizing the status of knowledge and then use the IPCC as a springboard from which we, the US, want to FURTHER REFINE THE SCIENCE.

[DAB: It is important that we as a country are not SEEN as backing off or undercutting the IPCC process because of the many, many Presidential and Administration statements that we are supporting the IPCC process and its reports. We have, in fact, used this argument vehemently to keep us from other more radical committments on the greenhouse question.

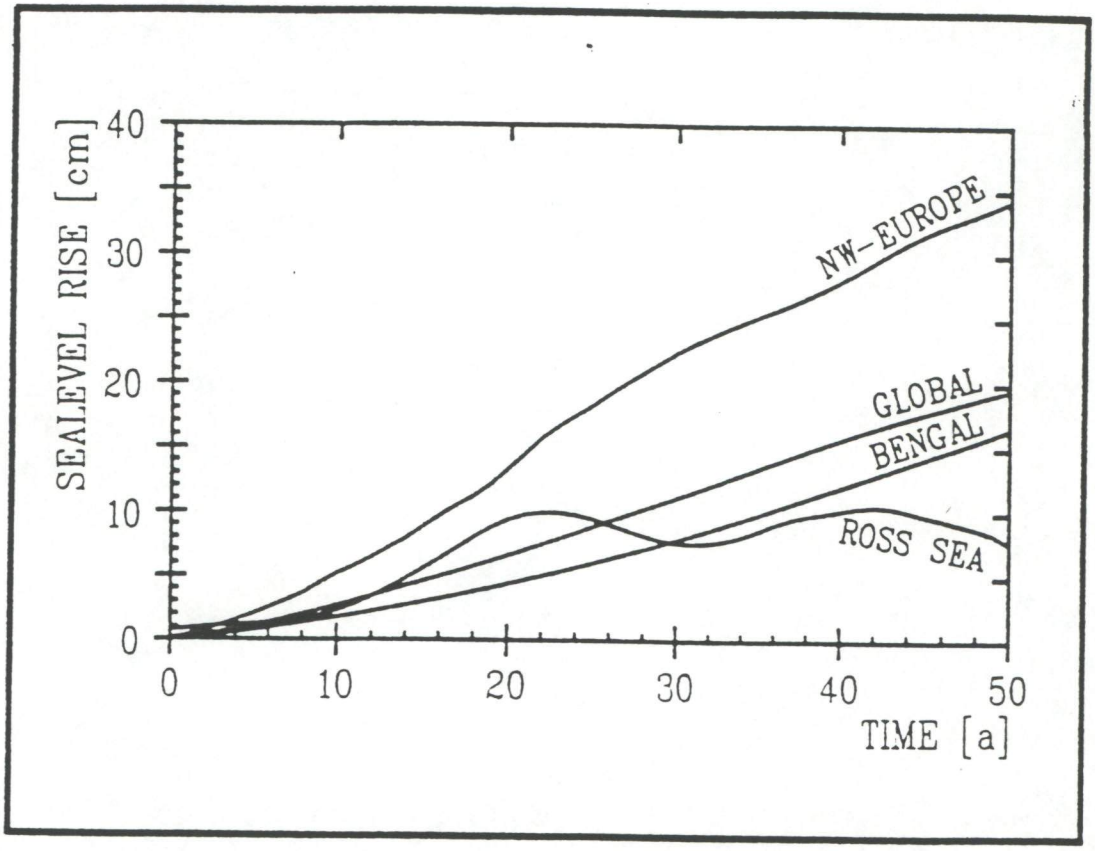
If we PUBLICALLY distance ourselves from this report, we will do significant further damage to our and the President's credibility in the national and international global change area. We will be seen as rejecting the report because we don't like the results. Bull's eye in the old foot again]

d. Darman's point about focussing so heavily on the anthropogenic greenhouse gas emissions sources and sinks - and no proper perspective - IS INCORRECT.

I have attached a copy of Section I "Greenhouse Gases and Aerosols" in which each gas is discussed in detail - including composition, feedbacks, sources, sinks, etc. Natural sources, sinks, fluxes etc are covered in great detail.

Max-Planck-Institut
für Meteorologie

REPORT No. 49



OCEAN RESPONSE TO GREENHOUSE WARMING

by

U. MIKOLAJEWICZ • B. SANTER • E. MAIER-REIMER

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Ocean Response to Greenhouse Warming

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Abstract

An ocean general circulation model is used to simulate the sea level change resulting from a rapid greenhouse warming. The changes in sea level and sea surface temperature are regionally strongly variable. The projected global mean sea level rise due to thermal expansion alone is 19 cm in 50 years. However, regional values can vary between 40 cm and even a decrease in sea level due to changes in ocean circulation. The simulated oceanic change patterns are compared with measurements.

1 Introduction

An increase in sea level is likely to be a first order impact of greenhouse-gas-induced climate change. Even moderate changes in sea level (less than 50 cm) can have tremendous societal and economic impacts, particularly in heavily-populated regions of the world which are close to sea level. Projecting regional changes in sea level is therefore extremely important.

Several recent studies have considered the transient response of coupled ocean-atmosphere models to time-dependent CO_2 and greenhouse-gas forcing (1,2,3), but have not discussed sea level changes. Virtually all studies which have examined the sea level response have used simple 1-D pure diffusive or upwelling-diffusive models (4,5) in which only thermal expansion is treated. These investigations cannot simulate the regional distribution of sea level change. The only study which has attempted to do this, including both thermal expansion and extremely simplified ocean dynamics, yielded spatially homogenous sea level changes (6). Here we consider both thermal effects and the full dynamic effects associated with changes in oceanic general circulation.

In the present study we isolate the purely oceanic response to a 'pseudo-transient' atmospheric forcing consisting of monthly mean surface air temperature anomalies ($2xCO_2$ minus $1xCO_2$) derived from atmospheric general circulation model (AGCM) equilibrium response experiments. We examine the robustness of certain features of the coupled models' oceanic response (such as inter-hemispheric asymmetry in the sea surface temperature (SST) changes) in a simpler uncou-

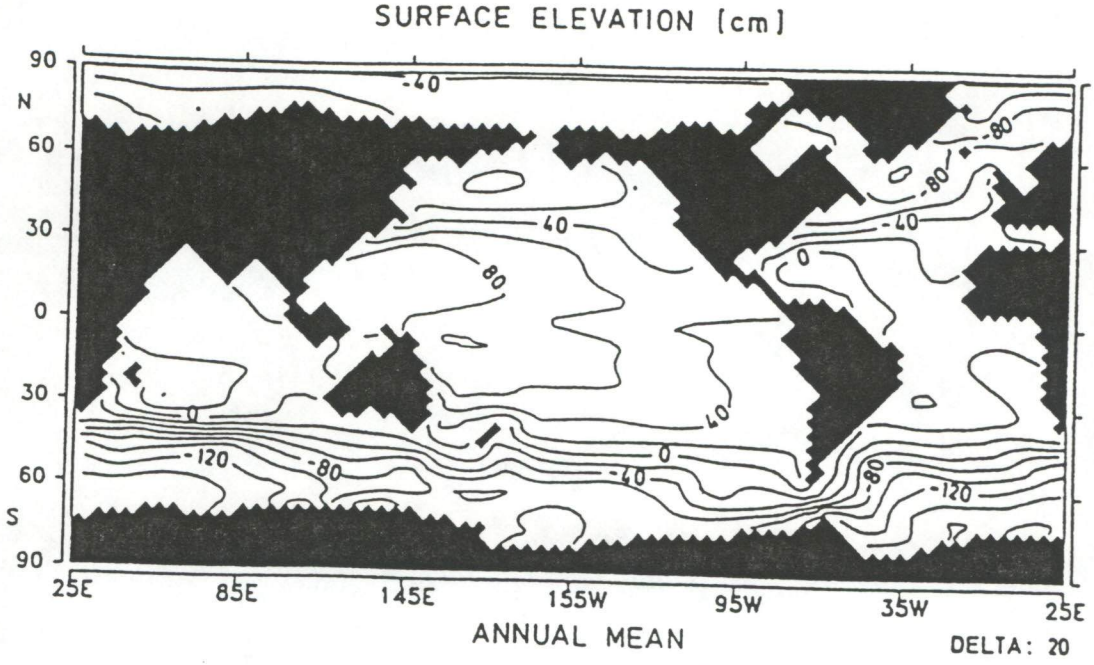

Figure 1a: Annual mean distribution of sea surface elevation of the control experiment.

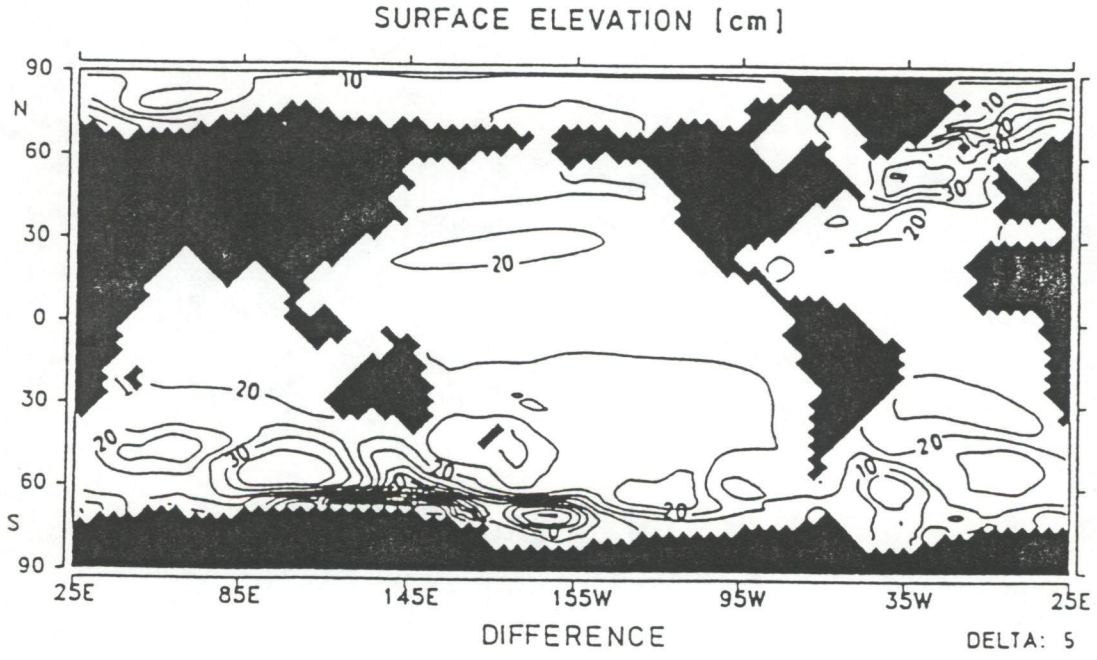

Figure 1b: Pattern of changes in sea surface elevation for year 50 relative to the control experiment. Note that changes in the Ross Sea area are negative.

pled experiment using an ocean general circulation model (OGCM) with realistic thermohaline circulation.

2 The model

We use the Hamburg large-scale-geostrophic OGCM (7). The model is based on the conservation laws for heat, salt and momentum (the latter in a linearized form) and uses the hydrostatic assumption. The flow field is divided into a vertically-averaged barotropic component and the residual baroclinic components. The model has a dynamically active sea surface elevation. Changes in the surface elevation are due to divergence of flow, thermal expansion and fresh water fluxes. The formulation of the model is fully implicit, so that a time step of 30 days can be used, as compared with a few hours typical for explicit integration schemes. A one-layer thermodynamic sea ice model with advection is included.

The horizontal resolution is 3.5 x 3.5 degrees on an E-type grid (8). The model has 11 vertical layers (centered at 25, 75, 150, 250, 450, 700, 1000, 2000, 3000, 4000 and 5000 m).

The model was spun up from an initially homogeneous state and integrated for 10000 years to steady state with climatological forcing (monthly mean wind stress (9) and air temperature (10) and annual mean climatological surface salinity (11)) coupled to the top layer with Newtonian time constants of approximately 2 months. During the last 500 years of spin up the fresh water fluxes required to restore the salinity to climatology were stored and used as forcing in a control run, for which the surface salinity was no longer prescribed but computed from the fresh water fluxes. Initially the model showed a slight drift with this type of forcing, but after a further 4000 years of integration the model again reached a steady state which was very close to the state attained before switching to fresh water flux forcing.

The model exhibits a realistic mean thermohaline circulation (12) with a flow of 17 Sverdrup (10 tons/sec) of North Atlantic deep water (NADW) leaving the Atlantic at 30°S to the Southern Ocean. At 24°N the strength of the meridional overturning is 20 Sverdrup compared to 17 Sverdrup derived from observations (13). The strength of the Antarctic Circumpolar current (ACC) is 122 Sverdrup, compared to 123 Sverdrup ± 10 from pressure gauge measurements (14). The annual mean sea surface elevation of the control run is displayed in figure 1a, showing the well-known subtropical gyres and the ACC. The equilibrium circulation fields attained after this procedure were used as initial conditions for the following experiment.

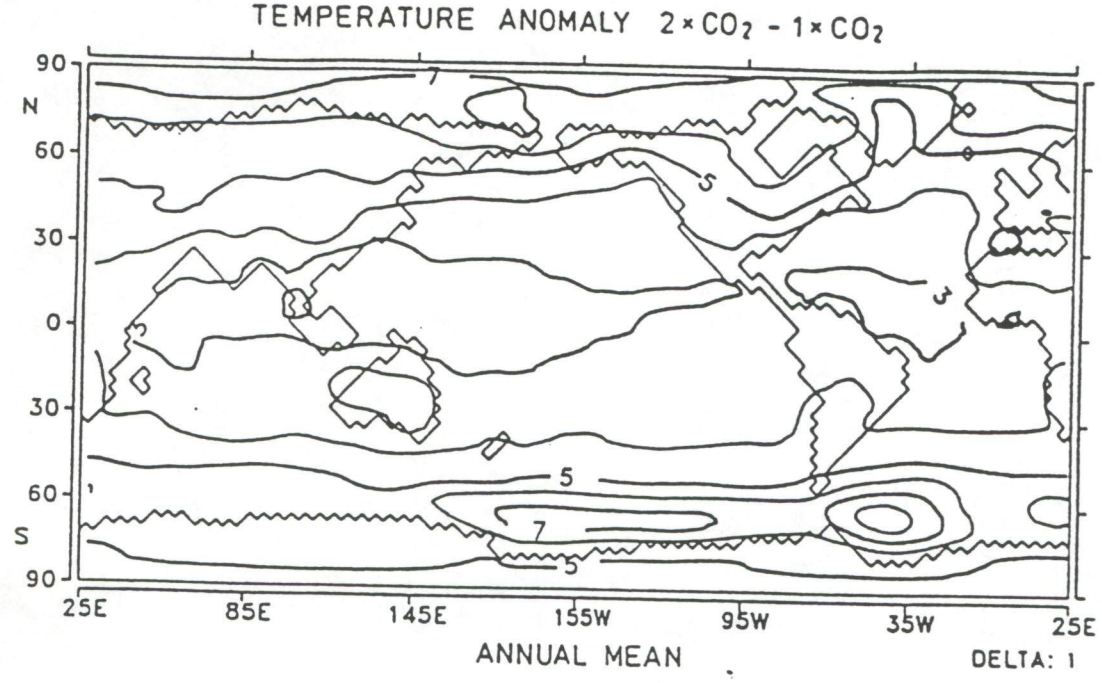

Figure 2a: Pattern of annual mean "model average" surface air temperature anomaly used as forcing for the simulation. The global mean of this temperature anomaly is 4°C (computed over ocean points only). For sources of model data see text.

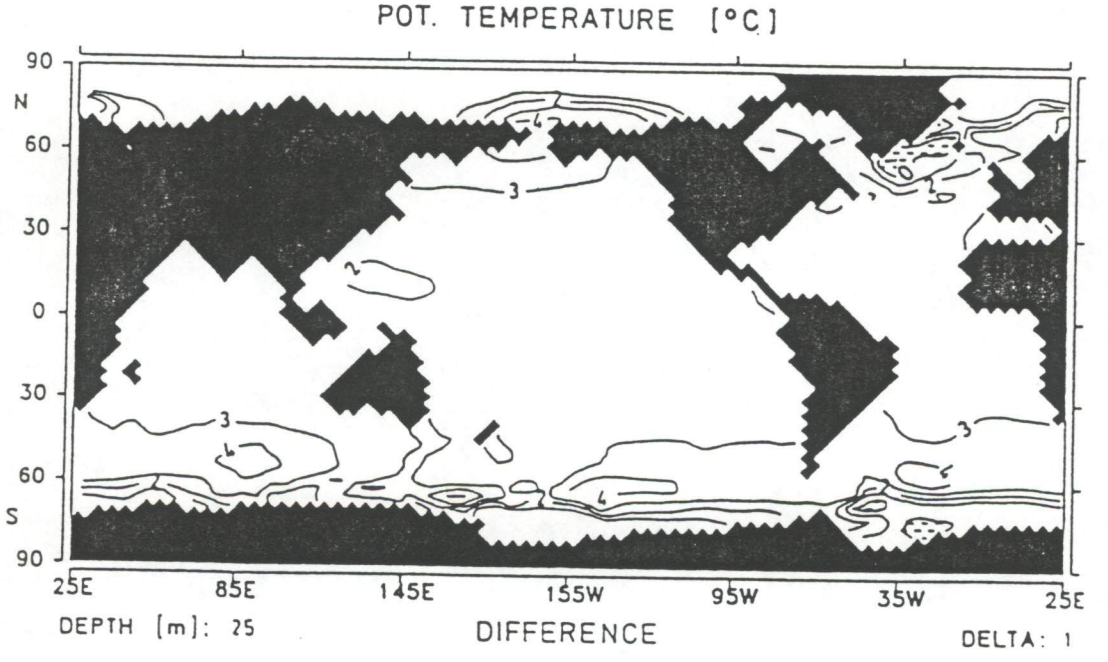

Figure 2b: Geographical distribution of changes in SST in year 50 relative to the control experiment. Shading indicates negative values.

3 The experiment

The ocean model was driven by monthly mean surface air temperature anomalies ($2xCO_2$ minus $1xCO_2$) derived from four equilibrium response experiments conducted with the Goddard Institute for Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), Oregon State University (OSU) and United Kingdom Meteorological Office (UKMO) AGCMs (15,16,17,18). All AGCMs were coupled with mixed-layer oceans. Rather than using results from a single model only, surface air temperature changes for the four models were interpolated to the OGCM grid and averaged. The resulting model average anomaly fields, defined as an annual cycle over 12 months, utilize all published equilibrium response results from models with comparable levels of atmosphere-ocean interaction, except for results from the National Center for Atmospheric Research (NCAR; 19), which were not available.

The patterns of $2xCO_2$ minus $1xCO_2$ surface temperature changes were very similar for the four models, with poleward amplification of the temperature change in the winter hemisphere due to ice-albedo feedback effects. The major inter-model differences were in the amplitudes of the surface temperature changes. Thus our averaging procedure should not significantly smooth the response patterns while being less biased by individual model sensitivities. The averaged monthly mean anomaly fields were positive everywhere with a mean warming of 4°C over the oceans. The annual mean spatial pattern of the applied temperature anomaly is shown in figure 2a.

We assumed that the model-average patterns are time-invariant, only the amplitude varying during the transition from $1xCO_2$ to $2xCO_2$. To simulate the expected transient temperature increase in response to time-dependent greenhouse-gas forcing, the amplitude evolution was described by the linear exponential function $f(t) = 1 - e^{-(t-t_0)/a}$ with a time constant $a = 40$ years. The initial time t_0 was set to January 1st for year 0. The time evolution of the mean forcing temperature changes over the oceans is shown in figure 3a; by the year 50 the projected warming is 2.9°C. The forcing due to possible changes in the wind stress and fresh water fluxes relative to the control run was not considered.

The neglect of atmospheric feedback, anomalous wind stress and fresh water flux forcing, and the assumption of time-invariant patterns of the surface temperature change in the forcing fields clearly represent major idealizations in our experimental design. Recent evidence from the few GCM experiments which have been performed with time-dependent greenhouse-gas forcing suggests in fact that important differences may exist between the equilibrium and transient response patterns (1,3,20). We stress that the experiment performed here must be regarded only as a zeroth order test of the sensitivity of the ocean circulation to a specified forcing, and not a prediction. However, we feel that such a test can give valuable insight into typical sea level response properties which may not have been generally appreciated and which would also apply to a more realistic coupled ocean-atmosphere

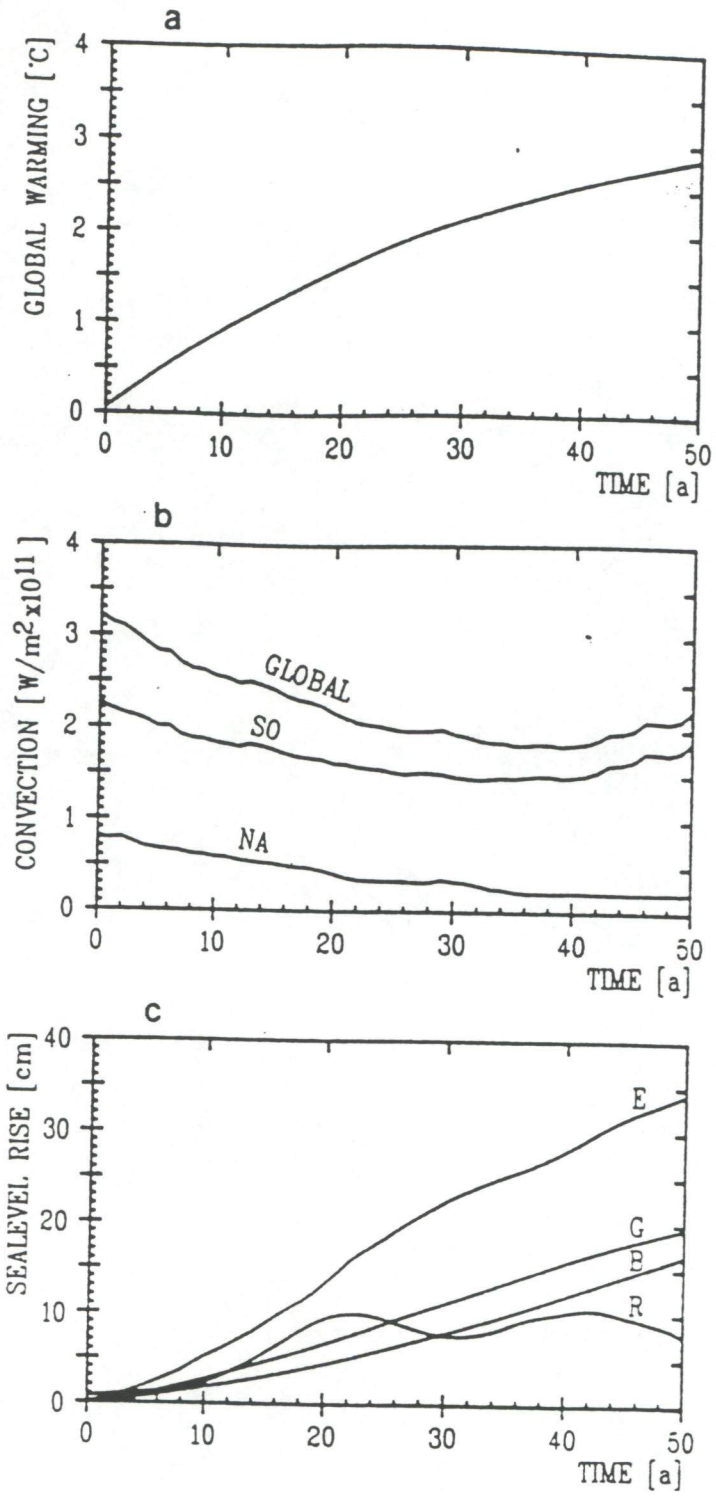

Figure 3a: Time evolution of annual mean globally averaged surface air temperature anomaly imposed on the OGCM.

Figure 3b: Time evolution of global, North Atlantic (NA) and Southern Ocean (SO) deep water formation, measured as rate of loss of potential energy due to convection.

Figure 3c: Sea level rise as a function of time: global mean (G), North West Europe (E), Ross Sea (R) and Bay of Bengal (B).

simulation.

4 Results

The time evolution of the deep water production (measured as the rate of loss of potential energy by convection) is shown in figure 3b. The global deep water production decreases initially and attains a minimum in year 40 (approximately 2/3 of its original value). The fractional reduction is stronger in the North Atlantic than in the Southern Ocean. After the year 40, the global deep water formation increases again. This can be attributed exclusively to increased formation of Antarctic Bottom water (AABW). Generally there is a trend in the deep water formation to a higher fraction of AABW compared to NADW.

Figure 2b displays the changes in SST for the year 50 relative to the control. Although the average surface air temperature anomalies are consistently positive throughout, for all space and time, with the largest values in the winter hemisphere at ice margins (see figure 2a), negative SST anomalies appear in the vicinity of the Irminger Sea and in the Weddell Sea. This pattern of local SST decrease (or much weaker increase than the rest of the ocean) is persistent throughout the entire experiment, with the largest decreases occurring in the Irminger Sea. This is the region in which the model produces most of its NADW in the control run. The result can be attributed to the suppressed production of deep water, and to a resultant reduction of the large convective heat flux from lower layers to the surface, which in the control run was responsible for the relatively warm temperatures in this region. The cooling process is accompanied by a freshening of surface waters in the North Atlantic and higher surface salinities at lower latitudes (figure 4).

A section through the western Atlantic (figure 5) shows the penetration of the warming signal into the deep ocean for the year 50. Except for polar regions, where the suppression of the upward deep convective heat flux is an efficient mechanism for warming the deep ocean, the warming is confined to the upper 1000 m. In the deep Atlantic, a cooling is seen. This is due to changes in the relative contribution of the different deep water sources, with an increased ratio in the production of cold, fresh AABW to warm, salty NADW.

The time evolution of the global mean sea level rise caused by thermal expansion is shown in figure 3c. In year 50 the global mean sea level rise is 19 cm. This is almost completely due to effects above the thermocline. The steady state sea level rise after 2000 years of integration is 51 cm. Whereas the prescribed atmospheric warming in year 50 has reached 72% of the equilibrium value, the response in global mean sea level is only 38.4%. Eighty years were required for the sea level to reach 50% of its equilibrium level, and 210 years to reach 75%. This clearly demonstrates the long time scales involved in the downward penetration of the

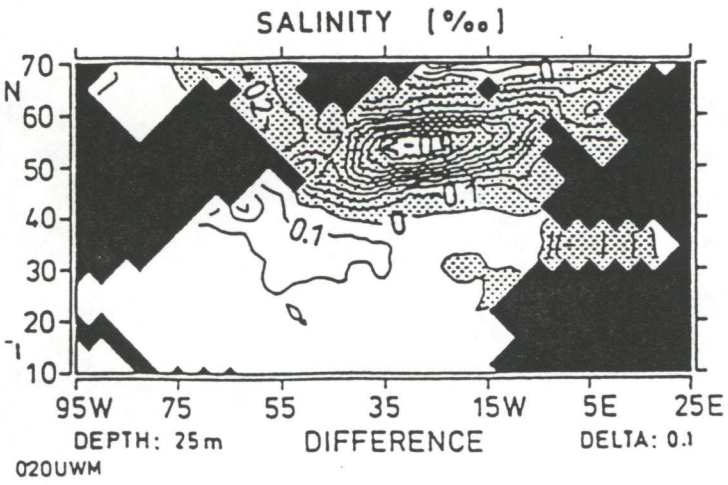

Figure 4: Geographical distribution of changes in the surface salinity in the North Atlantic in year 20 relative to the control experiment. Shading indicates negative values.

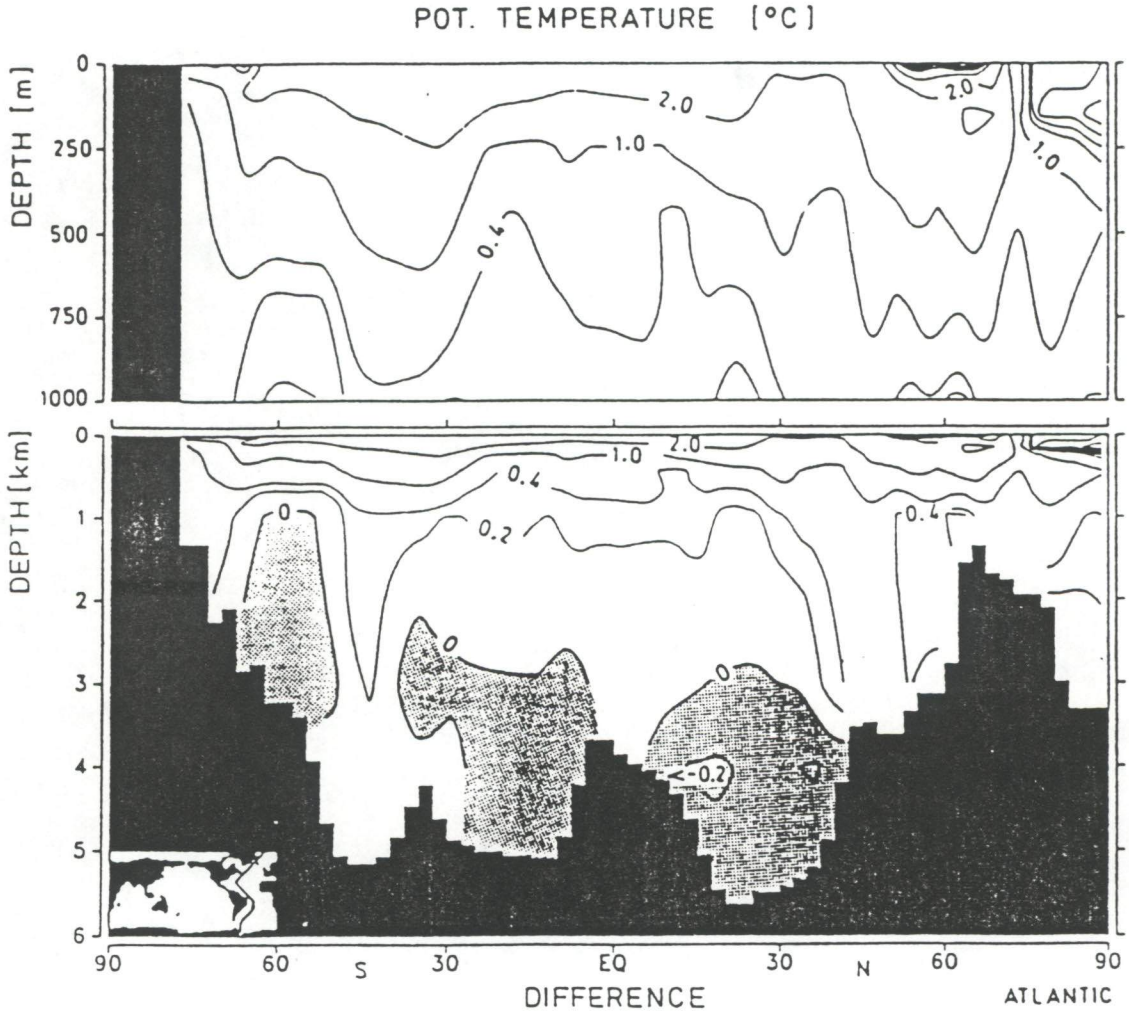

Figure 5: Pattern of change of potential temperature on a meridional section through the Atlantic in year 50 relative to the control experiment. The location of the section is shown in the insert. Shading indicates negative values.

warming signal.

The curves for selected locations differ considerably (figure 3c). The sea level increase of 35 cm in North-West Europe is almost twice as large as the global mean sea level change, while for example the increase in the Ross Sea is much smaller than the global mean. In general, the local sea level changes due to changes in the ocean circulation pattern are of the same magnitude as the changes due to the local thermal expansion, and both vary regionally.

The horizontal distribution of the sea level change for the year 50 is shown in figure 1b. The largest increases in sea level occur in the North Atlantic, as a result of the reduced NADW formation and reduced surface density, and on the northern edge of the ACC, through the southward displacement of the ACC. The increased gradient of sea level across the ACC is due to the larger fraction of bottom water produced at this location, as expressed by the increased vertical homogeneity of water mass properties.

5 Discussion

Coupled ocean-atmosphere models have not been used to investigate the sea level response to greenhouse-gas forcing (1,2,3). We are therefore restricted to comparing our sea level changes with results from simpler models.

Wigley and Raper (21) used an upwelling diffusive energy balance model to estimate the global sea level rise due to thermal expansion alone. For a comparable climate sensitivity ($\Delta T_{2x} = 4.5°C$) to that used here and "best guess" model parameters, they obtained an estimated global sea-level rise of 23 cm from 1985 to 2050. This is in good agreement with the global mean value obtained here (19 cm after 50 years).

With a simple model based on linear concepts of ventilation of the thermocline and Sverdrup balance, Godfrey et al.(6) arrived at a global sea level rise due to thermal expansion of between 13 and 30 cm after 60 years for an assumed global warming of 3°C in the first 40 years. This model also provides information on the spatial patterns of projected changes in sea-level. The authors obtain an almost uniform increase, with slightly weaker values around Antarctica. The disagreement with our results can be attributed to their neglect of changes in the deep water formation and the associated changes in the convective heat flux, which was found to be the most important effect in our experiment.

The circulation changes obtained here can be compared with those obtained in recent experiments with coupled ocean-atmosphere GCMs. A characteristic feature of our experiment, the cooling or reduced warming of SST in zones where deep water is produced, has been found also in a GFDL coupled AGCM-OGCM simulation with sector geography (1). The model's equilibrium response to CO_2-

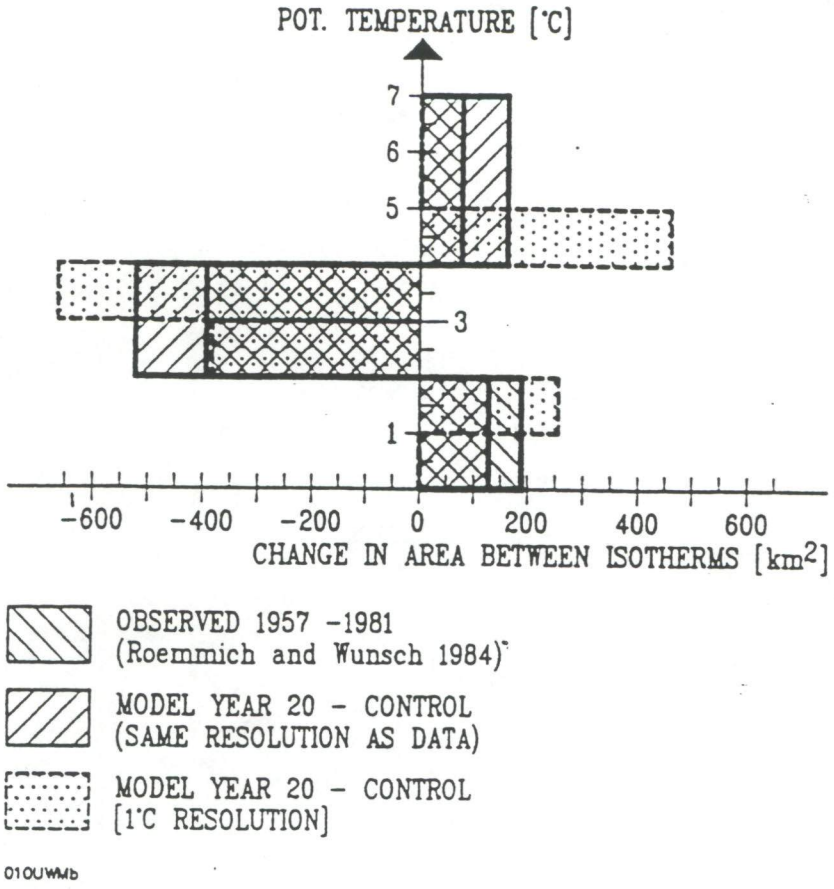

Figure 6: Observed vs. simulated relative changes in area between isotherms for a zonal Atlantic section at 24°N. In order to normalize the curves to the same bottom water temperature, 1°C has been subtracted from the model data. For the model results, two different resolutions have been plotted.

doubling yielded a cooling around Antarctica, with maxima located at the positions of strongest deep water formation in the control experiment. Due to an almost complete lack of NADW formation in this simulation, however, there was no equivalent cooling in the Northern Hemisphere.

The recent GFDL coupled AGCM-OGCM (3) simulation with a transient CO_2 increase of 1%/year (compound) shows similar results to those obtained in the present simulation. After 60 years of integration, the production of AABW is increased relative to NADW and in the zonal average a cooling is found in the deep ocean centered at 30° N (c.f. our figure 5). There is a relatively weak (compared to the zonal average) warming in the North Atlantic and a cooling around Antarctica. This pattern of SST changes generally corresponds to that obtained here, except for a discrepancy between our strong North Atlantic cooling and the weaker warming in the GFDL experiment. This discrepancy may be related to differences in the production of NADW, which is considerably weaker in the control run of the GFDL experiment than in our control run. The surface freshening which we obtain in the North Atlantic is also present in the GFDL simulation. The authors attribute this to a regional increase in runoff and precipitation minus evaporation, an explanation which cannot apply in our case.

The reduced production of NADW and the related cooling offers a possible explanation for the observed trend of decreasing marine air temperatures in the North Atlantic during the last 20 years, in contrast to the increase in Northern Hemisphere and Southern Hemisphere annually-averaged surface air temperature (22). Support for this conjecture is found in the observation of a strong negative salinity anomaly in the North Atlantic during the seventies. This anomaly was accompanied by suppression of convection and surface cooling (23). During this period the surface salinity further south (at ca. 40°N) was increased relative to the late fifties (24). A similar feature is found in the model response (figure 2b).

The simulated cooling in the deep Atlantic is consistent with the trend inferred from a comparison of temperature data taken in 1957 and 1981 for two transatlantic sections at 24°N and 36°N (25). Figure 6 shows the changes in areal coverage for observed (1981 minus 1957) and simulated (year 20 minus Control) isotherms for the section at 24°N. As the simulated deep water is roughly one degree warmer than the observations, the simulated curve has been reduced to the observed potential temperature in the bottom water by subtracting one degree from the simulated temperatures. The similarity between the two curves is striking.

However, although there are some striking similarities between the observed changes from the late fifties to the seventies and early eighties and the pattern which the model produces in response to the imposed warming, we stress that the observed anomalies could well be generated by other effects - for example, anomalous atmospheric circulation patterns (26). In the eighties the surface salinity in the North Atlantic was returning to its former values (23) and the relative cooling trend abated.

6 Conclusions

Significant changes are induced in the ocean circulation in response to an imposed forcing in surface air temperature corresponding to GCM equilibrium response results for a CO_2 doubling. In regions where deep water formation was formerly active, the projected increase in SST is small or even decreases relative to the zonal average. The formation of NADW is more strongly suppressed than the formation of AABW. The subsequent changes in deep water temperatures and salinities result in an effective cooling of the deep Atlantic. This signal may be useful in the detection of CO_2-induced climate change, although signal-to-noise problems are even more serious in the deep ocean than for surface data due to the sparseness of observations. Recently, the measurement of acoustic travel times has been proposed as a technique for monitoring deep ocean temperature changes associated with a CO_2 warming (27). The present experiment stresses the need for reliable ocean circulation response studies to compute the magnitude (and even sign!) of the expected temperature changes.

The projected atmospheric warming of ca. 3°C by the year 50 leads to a global sea level rise of 19 cm due to thermal expansion effects alone. Thermal expansion, however, is only one component of the simulated sea level response. Regionally-specific changes in the dynamic topography of the sea surface are of the same magnitude, with the strongest increases predicted in the North Atlantic, and the weakest increases (or even a decrease) predicted for the Ross Sea. Simpler models without a dynamic ocean cannot treat such effects in a realistic way. This shows the need for using an OGCM with realistic ocean circulation (particularly for the deep ocean) to simulate the regional sea-level changes in response to greenhouse-gas forcing.

The decrease in global deep water formation rates must be expected to have a strong impact on the atmospheric CO_2 content. At present, a significant fraction of the emitted CO_2 is transported with the newly-formed deep water to the deep ocean, thus limiting the increase in atmospheric pCO_2 (7). If the efficiency of this marine transport and storage mechanism is reduced. the increase in atmospheric pCO_2 will be amplified. This positive feedback can have important consequences for the evolution of future atmospheric pCO_2 concentrations.

Acknowledgements

Discussions with Klaus Hasselmann, Tom Wigley and Syd Levitus helped to improve this paper substantially. We gratefully acknowledge the assistance of Marion Grunert in preparing the diagrams.

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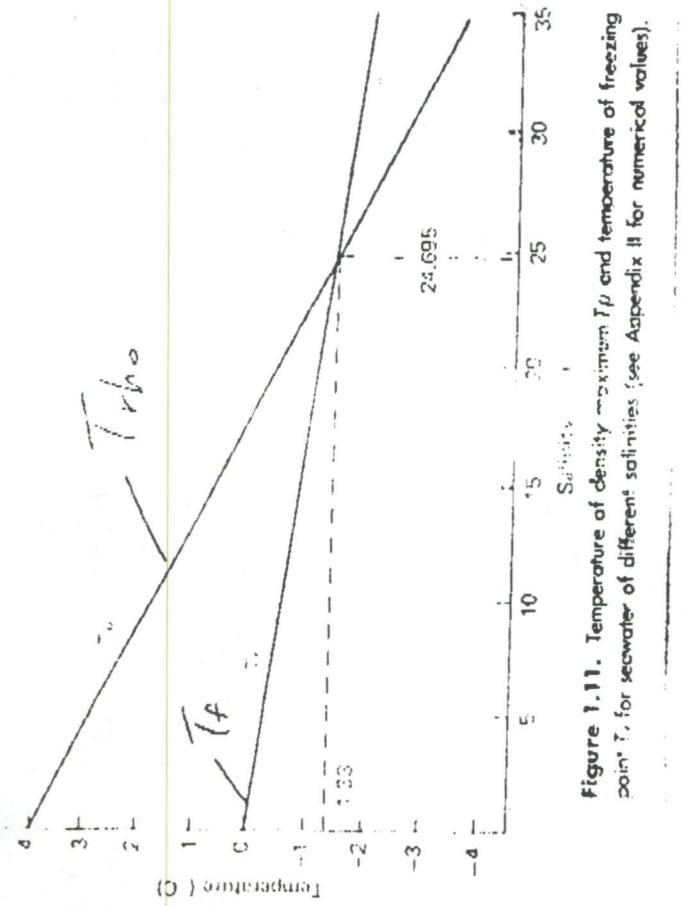

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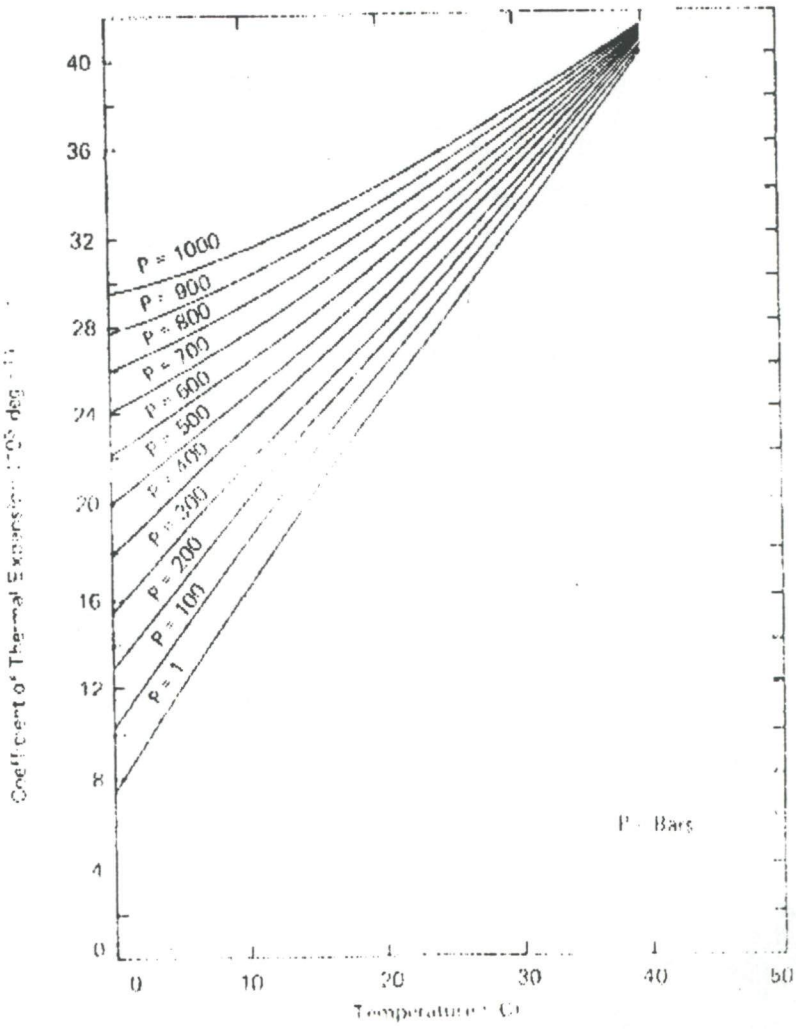

Figure 1.9. Coefficient of thermal expansion of seawater at a salinity of 35‰ as a function of temperature and pressure. It increases with pressure and temperature (see Appendix II for numerical values).

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3 June 1990

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Fred K

VOLUME PROPERTIES OF ORDINARY WATER

G. S. KELL

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(Specific volume v, density ρ, thermal expansivity $\alpha = \mathrm{d} \ln v/\mathrm{d}t = -\mathrm{d} \ln \rho/\mathrm{d}t$, compressibility $\kappa = -\mathrm{d} \ln v/\mathrm{d}p = \mathrm{d} \ln \rho/\mathrm{d}p$)

t, °C.	v, Cc./G.	ρ, G./Ml.	$10^6\alpha$, Deg.$^{-1}$	$10^6\kappa$, Bar^{-1}
−20	1.00658	0.99349	−678.48	61.94
−18	1.00532	0.99474	−580.83	60.48
−16	1.00424	0.99581	−495.74	59.11
−14	1.00332	0.99672	−420.85	57.83
−12	1.00254	0.99749	−354.33	56.64
−10	1.001895	0.998137	−294.73	55.52
−9	1.001614	0.998417	−267.18	54.99
−8	1.001359	0.998671	−240.95	54.48
−7	1.001131	0.998899	−215.94	53.98
−6	1.000926	0.999102	−192.06	53.50
−5	1.000746	0.999283	−169.22	53.04
−4	1.000587	0.999441	−147.34	52.60
−3	1.000451	0.999578	−126.36	52.17
−2	1.000334	0.999694	−106.20	51.76
−1	1.000238	9.999790	−86.81	51.36
0	1.000160	0.999868	−68.14	50.98
1	1.000101	0.999927	−50.14	50.61
2	1.000060	0.999968	−32.77	50.26
3	1.000036	0.999992	−15.98	49.92
4	1.000028	1.000000	0.26	49.59
5	1.000036	0.999992	15.98	49.28
6	1.000060	0.999968	31.23	48.98
7	1.000098	0.999930	46.01	48.69
8	1.000151	0.999877	60.37	48.41
9	1.000219	0.999809	74.33	48.15
10	1.000300	0.999728	87.90	47.89
11	1.000395	0.999634	101.12	47.65
12	1.000502	0.999526	113.99	47.42
13	1.000623	0.999406	126.54	47.19
14	1.000755	0.999273	138.78	46.98
15	1.000900	0.999129	150.73	46.78
16	1.001057	0.998972	162.41	46.59
17	1.001225	0.998804	173.82	46.40
18	1.001405	0.998625	184.99	46.23
19	1.001596	0.998435	195.91	46.06
20	1.001797	0.998234	206.61	45.91
21	1.002010	0.998022	217.10	45.76
22	1.002232	0.997801	227.37	45.62
23	1.002465	0.997569	237.45	45.48
24	1.002708	0.997327	247.34	45.36
25	1.002961	0.997075	257.05	45.24
26	1.003224	0.996814	266.59	45.13
27	1.003496	0.996544	275.96	45.02
28	1.003778	0.996264	285.17	44.93
29	1.004069	0.995976	294.23	44.84
30	1.004369	0.995678	303.14	44.75
31	1.004678	0.995372	311.92	44.67
32	1.004995	0.995057	320.55	44.60
33	1.005322	0.994734	329.06	44.54
34	1.005657	0.994403	337.44	44.48

t, °C.	v, Cc./G.	ρ, G./Ml.
48	1.011194	0.988957
49	1.011647	0.988515
50	1.012107	0.988066
51	1.012574	0.987610
52	1.013048	0.987148
53	1.013529	0.986680
54	1.014017	0.986205
55	1.014512	0.985723
56	1.015014	0.985236
57	1.015522	0.984743
58	1.016038	0.984243
59	1.016560	0.983737
60	1.017089	0.983226
61	1.017625	0.982708
62	1.018167	0.982185
63	1.018716	0.981655
64	1.019271	0.981120
65	1.019833	0.980580
66	1.020402	0.980034
67	1.020977	0.979482
68	1.021558	0.978924
69	1.022146	0.978361
70	1.022740	0.977793
71	1.023340	0.977219
72	1.023947	0.976640
73	1.024560	0.976056
74	1.025180	0.975466
75	1.025805	0.974871
76	1.026437	0.974271
77	1.027076	0.973665
78	1.027720	0.973055
79	1.028371	0.972439
80	1.029027	0.971819
81	1.029690	0.971193
82	1.030360	0.970562
83	1.031035	0.969926
84	1.031716	0.969286
85	1.032404	0.968640
86	1.033098	0.967990
87	1.033797	0.967335
88	1.034503	0.966674
89	1.035216	0.966009
90	1.035934	0.965340
91	1.036658	0.964665
92	1.037389	0.963980
93	1.038125	0.963301
94	1.038868	0.962615
95	1.039617	0.961920
96	1.040372	0.961220
97	1.041133	0.960510

ON THE QUESTION OF SEA LEVEL RISE, THE FOLLOWING, ZERO ORDER, BACK OF THE ENVELOPE CALCULATION MAY HELP. YOU NEED ONE EQUATION, AND ONE "CONSTANT"

p = PRESSURE

T = TEMPERATURE

ρ = DENSITY OF SEAWATER

g = GRAVITY

h = DEPTH ~~OF OCEAN~~

HYDROSTATIC EQUATION $p = \rho g h$

THERMAL EXPANSION $\alpha = -\frac{1}{\rho}\frac{\partial \rho}{\partial T}$

AS WATER EXPANDS, SEA LEVEL RISES, BUT THERE IS NO CHANGE IN PRESSURE

$$\partial p = 0 = \partial \rho g h + \rho g \partial h$$

$$-\partial \rho g h = \rho g \partial h$$

$$\alpha \rho \partial T h = \rho \partial h$$

$$\frac{\partial h}{\partial T} = \alpha h$$

$\bar{h} \cong 3800\,m$

$\alpha = f(T, S, p) \cong 10\text{-}20 \times 10^{-5}/^{\circ}C$ (S: SALINITY)

$$\frac{\partial h}{\partial T} \cong 15 \times 10^{-5} \times 3800\,m$$

$$\cong 60\,cm/^{\circ}C$$

A TENTH OF A DEGREE INCREASE IN THE AVERAGE OCEAN TEMPERATURE WOULD PRODUCE A 6 CM RISE IN SEA LEVEL, AS WOULD A $0.4^{\circ}C$ RISE IN THE TOP 1000m AND NO INCREASE IN THE BOTTOM 3000M.

IN A QUICK REVIEW OF IPCC-WG-1 I DID NOT FIND A PLOT OF ΔT VERSUS z^* SO THAT I COULD MAKE AN ESTIMATE OF SEA LEVER RISE.

* FOR THE OCEAN AS A RESULT OF SOME SPECIFIED INCREASE IN GREENHOUSE GASES

John Kutzbach

June 3, 1990

15 June 1990

Dr. Nancy Maynard
OSTP
Old Executive Office Building

Dear Nancy,

I just returned from a week at Scripps for a site visit, but managed to locate an interesting report on sea level change which I have enclosed. I got it from Walter Munk who had just returned from a visit with Klaus Hassleman of the Max Planck Institute in Hamburg.

The report is a study of the ocean response to greenhouse warming, as yet unpublished. The authors have run an ocean model that is forced by a model atmosphere modified by CO2 increase. Their focus is on the sea level change that results from the atmospheric forcing. In their case, the projected temperature increase in the atmosphere is 3 degrees over the next 50 years. As noted in their abstract, this produces a sea level change of 19 cm due to thermal expansion alone.

In our discussions last week, I suggested that the thermal expansion portion was the principal cause of change, but the authors have also explicitly evaluated the sea level alteration that is due to modifications of the ocean circulation due to the altered atmospheric conditions. It is this result that is shown on the cover of the paper.

The report is rather straightforwrd and clear, but I would be pleased to discuss it and other related ones I have found with you or Dr. Bromley if it would be of value.

I am still planning to prepare a few pages as we suggested, but this paper seemed so appropriate, I wanted to share it with you ASAP.

Regards,

Tom Spence

NATIONAL SCIENCE FOUNDATION

Office of the Deputy Director

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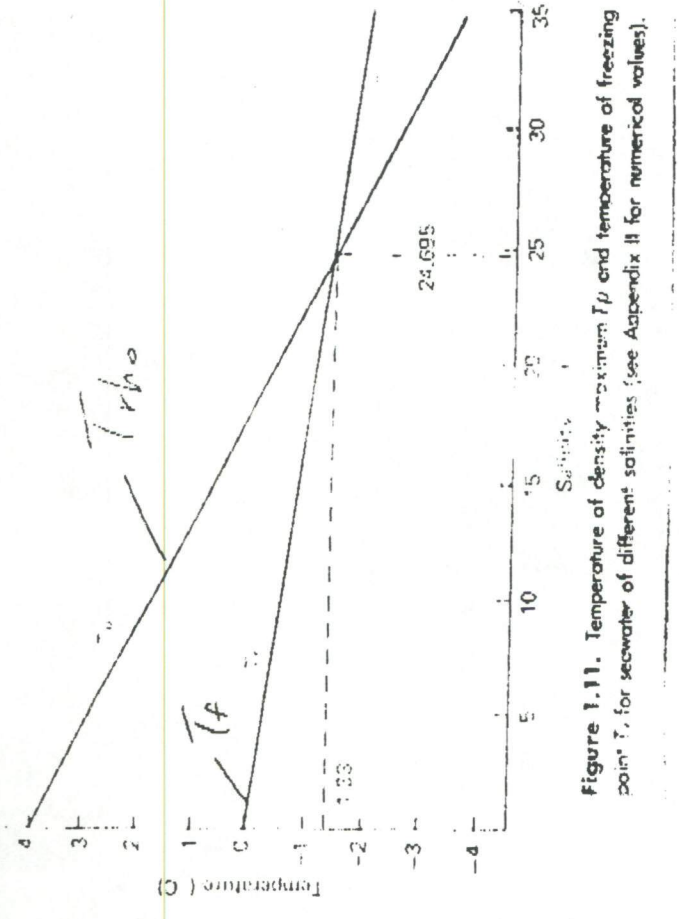

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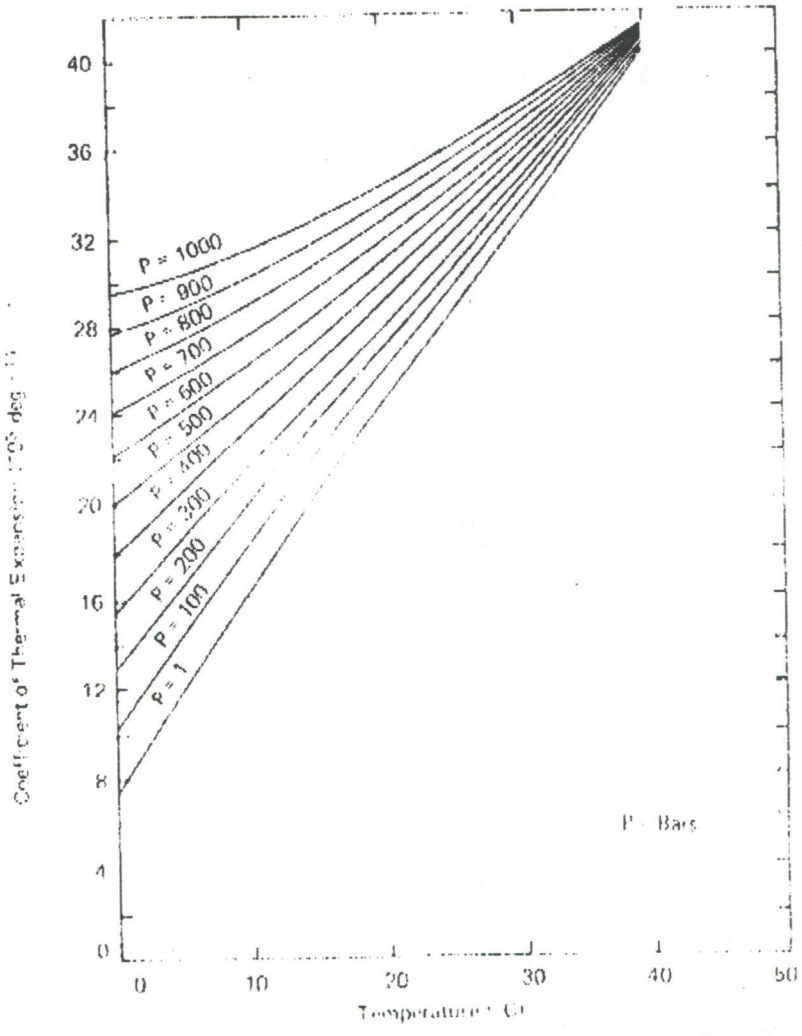

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76	1.026437	0.974271
77	1.027076	0.973665
78	1.027720	0.973055
79	1.028371	0.972439
80	1.029027	0.971819
81	1.029690	0.971193
82	1.030360	0.970562
83	1.031035	0.969926
84	1.031716	0.969286
85	1.032404	0.968640
86	1.033098	0.967990
87	1.033797	0.967335
88	1.034503	0.966674
89	1.035216	0.966009
90	1.035934	0.965340
91	1.036658	0.964665
92	1.037389	0.963980
93	1.038125	0.963302
94	1.038868	0.962613
95	1.039617	0.961920
96	1.040372	0.961220
97	1.041133	0.960513

ON THE QUESTION OF SEA LEVEL RISE, THE FOLLOWING, ZERO ORDER, BACK OF THE ENVELOPE CALCULATION MAY HELP. YOU NEED ONE EQUATION AND ONE "CONSTANT."

p = PRESSURE

T = TEMPERATURE

ρ = DENSITY OF SEAWATER

g = GRAVITY

h = DEPTH ~~OF OCEAN~~

HYDROSTATIC EQUATION $p = \rho g h$

THERMAL EXPANSION $\alpha = -\frac{1}{\rho}\frac{\partial \rho}{\partial T}$

AS WATER EXPANDS, SEA LEVEL RISES, BUT THERE IS NO CHANGE IN PRESSURE

$$\partial p = 0 = \partial P g h + \rho g \partial h$$

$$-\partial P g h = \rho g \partial h$$

$$\alpha \rho \partial T h = \rho g \partial h$$

$$\frac{\partial h}{\partial T} = \alpha h$$

$h \cong 3800\,m$

$\alpha = f(T, S, p) \cong 10\text{-}20 \times 10^{-5}/^{\circ}C$

(S: SALINITY)

$$\frac{\partial h}{\partial T} \cong 15 \times 10^{-5} \times 3800\,m$$

$$\cong 60\,cm/^{\circ}C$$

A TENTH OF A DEGREE INCREASE IN THE AVERAGE OCEAN TEMPERATURE WOULD PRODUCE A 6 CM RISE IN SEA LEVEL, AS WOULD A 0.4°C RISE IN THE TOP 1000m AND NO INCREASE IN THE BOTTOM 3000M.

IN A QUICK REVIEW OF IPCC-WG-1 I DID NOT FIND A PLOT OF ΔT VERSUS z^* SO THAT I COULD MAKE AN ESTIMATE OF SEA LEVER RISE.

* FOR THE OCEAN AS A RESULT OF SOME SPECIFIED INCREASE IN GREENHOUSE GASES

John Kutzbach

June 3, 1990

15 June 1990

Dr. Nancy Maynard
OSTP
Old Executive Office Building

Dear Nancy,

I just returned from a week at Scripps for a site visit, but managed to locate an interesting report on sea level change which I have enclosed. I got it from Walter Munk who had just returned from a visit with Klaus Hassleman of the Max Planck Institute in Hamburg.

The report is a study of the ocean response to greenhouse warming, as yet unpublished. The authors have run an ocean model that is forced by a model atmosphere modified by CO2 increase. Their focus is on the sea level change that results from the atmospheric forcing. In their case, the projected temperature increase in the atmosphere is 3 degrees over the next 50 years. As noted in their abstract, this produces a sea level change of 19 cm due to thermal expansion alone.

In our discussions last week, I suggested that the thermal expansion portion was the principal cause of change, but the authors have also explicitly evaluated the sea level alteration that is due to modifications of the ocean circulation due to the altered atmospheric conditions. It is this result that is shown on the cover of the paper.

The report is rather straightforwrd and clear, but I would be pleased to discuss it and other related ones I have found with you or Dr. Bromley if it would be of value.

I am still planning to prepare a few pages as we suggested, but this paper seemed so appropriate, I wanted to share it with you ASAP.

Regards,

Tom Spence

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Nancy M.

THE WHITE HOUSE

WASHINGTON

August 7, 1990

MEMORANDUM FOR CHRIS DAWSON
MIKE DELAND
TERESA GORMAN
BOB GRADY
BOYDEN GRAY
HENSON MOORE
BILL REILLY
DICK SCHMALENSEE

FROM: STEVE DANZANSKY

SUBJECT: Letter on IPCC Conclusions Paper

Attached for your review is a draft letter from Fred Bernthal to Bert Bolin, which spells out the U.S. views on the most recent draft of the IPCC Overview and Conclusions Paper. The letter represents a compilation of the major comments from the various departments and agencies involved in the PCC that has been preparing for the upcoming IPCC meeting in Sweden, and has previously been reviewed by the members of the PCC. It is critical that the letter be sent to Bolin this week, so please review it at your earliest convenience and provide comments to Barry McBee at 456-2800 (or by fax at 456-2223) by 11:30 a.m. tomorrow.

prepared for review by special SLP to meet with Sununu at 11:30 8/8

(meeting was cancelled 8/8 at 10 + rescheduled for 8/9 4pm)

Revised, 8/7/90, 4:00 p.m.

Professor Bert Bolin
Department of Meteorology
University of Stockholm
S10691 Stockholm, Sweden

Dear Bert:

At the outset, I want to thank you for your careful consideration of the points raised in my previous letter. I realize that a wide range of comments had to be taken into account following our meeting in Geneva, and I commend your work in synthesizing these ideas into the July 1990 Draft IPCC Overview and Conclusions Paper.

I have a number of additional comments to offer on behalf of the United States.

There is concern that the careful balance which was struck in the Working Groups on a number of issues has not been maintained in this draft. We recognize that in summarizing the underlying reports of the Working Groups it is necessary to use portions of each rather than the whole. For this reason, you may wish to consider a significantly shorter Overview and Conclusions document, drawing heavily on the three Executive Summaries, to which the underlying Summaries for Policymakers would be attached.

In addition, Section VI, "Strategies for the Future", goes significantly beyond the results of the IPCC assessment effort. We would suggest that this section be moved to the very beginning of the document and be titled IPCC Chairman's Introduction (as is done in the RSWG Summary for Policymakers).

Other comments are outlined below:

<u>Science and Impacts Issues</u>:

- The current draft still understates the fundamental scientific uncertainties regarding possible climate change. To put the scientific understanding of this issue in perspective, the fact that there are significant uncertainties regarding the timing, magnitude and regional distribution of climate changes should be highlighted with a separate heading.

- Scientific findings are expressed with a higher degree of confidence than is warranted (e.g. the words "will" or "would" are used throughout rather than "may" or "could") and in some cases worst-case figures are used rather than a mean figure or the full range of figures.

- A more extensive discussion of the relative impacts of all the greenhouse gases is needed in the science section. We suggest including the table on Global Warming Potentials (GWPs) from the WGI Policymakers Summary, with appropriate introductory language.

- In general, the discussion of possible climate change impacts places undue emphasis on the potential negative consequences of climate change, while minimizing potential positive impacts.

Response Options:

- A continuing concern is that the discussion of WGIII Task A does not reflect the uncertainties surrounding these exercises. It is important to make clear that these scenarios are not projections or predictions, but are based on varying assumptions. The explanation of how they were formulated should be taken from the WGIII Summary for Policymakers, Sections 3.1 and 3.2. and be placed in a separate section at the beginning of the document (not in an appendix).

- The report does not adequately address the uncertainties and lack of information policy makers face in dealing with climate change. To place the issue in perspective, it is important to include the language contained in the RSWG report that:

> "The information available to make sound policy analyses is inadequate because of: (a) remaining scientific uncertainties regarding the magnitude, timing, rate, and regional consequences of potential climate change; (b) uncertainty with respect to how effective specific response options or groups of options would be in actually averting potential climate change; and (c) uncertainty with respect to the cost, effects on economic growth, and other economic and social implications of specific response options or groups of options. The potentially serious consequences of climate change on the global environment, however, give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of such significant uncertainties."

- There is little discussion of the fact that the RSWG did not have time to consider the vital social and economic issues which are necessary for devising sound policies to address climate change. This point should be set forth prominently at the beginning of the Overview and Conclusions paper to place the IPCC's work in its proper perspective.

- Some of the economic concepts are not accurately stated. For example:

  -- The definition of "no regrets" policies on page 31 is incorrect. The current wording implies that such policies include actions which have <u>any</u> benefits beyond than those related to climate change, whereas the WGIII report refers to those actions which are justified in their own right.

  -- The discussion of the comprehensive approach does not describe its benefits. We suggest drawing from the WGIII Summary for Policymakers (p. 38, lines 10-13) to make clear that such an approach would advance environmental protection and minimize economic costs.

  -- The description of the "tragedy of the commons" on page 30 (lines 12-16) is flawed as written. This section would be substantially improved if restated along the following lines:

  > "If individual countries continue to pollute while others pay the costs of global pollution control, this will encourage nations to avoid mutually advantageous cooperative action."

- Given the target audience, it is important to specify throughout the report the baselines being used: Are the emissions changes from present levels or from projected future growth levels?

- The report does not adequately address the important role of sinks and the possibilities either for expanding sink resources or for implementing adaptation strategies.

- The current draft overstates the ability of the industrialized countries to reduce global emissions regardless of events in the rest of the world. The language from the WGIII Summary for Policymakers that "Developing countries should, within the limits feasible, take measures to suitably adapt their economies" needs to be included in the Executive Summary.

- The discussion of "narrowing the gap between the industrialized and developing world" would be more accurately characterized as follows:

"Improved economic performance and living standards in the developing world are important to developing a full global partnership to deal with the climate change issue."

These are some of the main comments I would like to bring to your attention as you continue preparations for the Sundsvall meeting. In order to assist in this process, the United States is developing more extensive comments and specific proposed wording changes.

I look forward to working together to develop a final IPCC paper which reflects the findings of the IPCC Working Groups. I am optimistic that the IPCC report will promote a reasoned and effective international response to this important issue.

Very best regards,

Frederick M. Bernthal

Revised, 8/7/90, 4:00 p.m.

Professor Bert Bolin
Department of Meteorology
University of Stockholm
S10691 Stockholm, Sweden

Dear Bert:

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- In general, the discussion of possible climate change impacts places undue emphasis on the potential negative consequences of climate change, while minimizing potential positive impacts.

Response Options:

- A continuing concern is that the discussion of WGIII Task A does not reflect the uncertainties surrounding these exercises. It is important to make clear that these scenarios are not projections or predictions, but are based on varying assumptions. The explanation of how they were formulated should be taken from the WGIII Summary for Policymakers, Sections 3.1 and 3.2. and be placed in a separate section at the beginning of the document (not in an appendix).

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> "The information available to make sound policy analyses is inadequate because of: (a) remaining scientific uncertainties regarding the magnitude, timing, rate, and regional consequences of potential climate change; (b) uncertainty with respect to how effective specific response options or groups of options would be in actually averting potential climate change; and (c) uncertainty with respect to the cost, effects on economic growth, and other economic and social implications of specific response options or groups of options. The potentially serious consequences of climate change on the global environment, however, give sufficient reasons to begin by adopting response strategies that can be justified immediately even in the face of such significant uncertainties."

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These are some of the main comments I would like to bring to your attention as you continue preparations for the Sundsvall meeting. In order to assist in this process, the United States is developing more extensive comments and specific proposed wording changes.

I look forward to working together to develop a final IPCC paper which reflects the findings of the IPCC Working Groups. I am optimistic that the IPCC report will promote a reasoned and effective international response to this important issue.

Very best regards,

Frederick M. Bernthal

Gov. Sununu's proposed change		Point # in 7/5 Bernthal letter	location of Change in Executive Summary	location of Change in Overview + Conclusions Doc.
Point #	Proposed change			
1	Improve discussion of natural sources + sinks	3, 6	p. i, l. 31-43	p.4, l. 35-50
2	Carbon cycle - need range of values	6		p. 4. l. 35-50
3	Include Comprehensive Approach	7		p.16, l. 10-23, 37-44
4	Include natural sinks as potential means for stabilization of atmospheric CO_2	6		p.4. l. 46-50
5	Additional Comment on uncertainties in underlying science	1, 2	p.ii, l. 20-27 p.ii, l. 43-52	
6	Too much focus on CO_2, augment discussion of other greenhouse gases	5		p.17, l. 32-56 p.18, l. 1-6

CLIMATE CHANGE POLICY PROSPECTUS

4th IPCC Plenary (Sundsvall, Sweden Aug. 26-?)

Agenda:

- Approve final IPCC report ("Policymakers Summary")
- Future workplan of IPCC (and structure of IPCC?)

Issues:

- Science (cf. Bernthal letter to Bolin of ~~8/5/90~~ 7/5/90):

  -- Uncertainties;
  -- Natural vs. anthropogenic fluxes;
  -- Comprehensive approach (sources and sinks)
  -- "Emissions Scenarios"

- Legal issues--comprehensive approach
- Extraneous material (e.g. "tragedy of the commons"; world poverty, etc. etc.) Possible remedy: Chairman's introduction.
- Material for IPCC summary to be drawn directly from Working Group summaries?
- Key, "fall-on-sword" issues for U.S.?

UNEP-WMO "Bureau" Meeting(s); Geneva, Nairobi

Agenda:

- Draft resolution for 2nd World Climate Conference (November in Geneva)
- When and how climate change convention negotiations will be conducted (e.g. secretariat; IPCC role)
- Preparatory meeting (Sept. or Oct.?) agenda

Issues:

- U.S. to host in Feb. 1991 (date, place, U.S. role)
- Structure of a convention: strictly framework (per Geneva Convention on stratospheric ozone) or other?

- The "slippery slope": U.S. to date agreed only to provision for subsequent consideration of protocols in a framework convention
- Format & procedure in negotiations (previous similar negotiations tightly controlled by UNEP D-G Tolba)
- Level of negotiators; U.S. negotiator; chair

Second World Climate Conference (Oct. 29-Nov. 7):

Agenda:

- Scientific meeting, including IPCC report
- Political ("Ministerial" meeting)--Noordwijk-II

Issues:

- U.S. representative at ministerial--level??
- Draft resolution for ministerial

Forestry Convention

Issues:

- Separation from IPCC negotiation
- How to be handled by USG?

######

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

nsf

OFFICE OF THE
DEPUTY DIRECTOR

July 5, 1990

Professor Bert Bolin
Department of Meteorology
University of Stockholm
S10691 Stockholm
Sweden

Dear Bert:

My congratulations on the careful and thoughtful effort you have put into drafting both the IPCC executive summary and the overview and conclusions. I suspect that the meeting in Geneva was a useful preview for what to expect in Sundsvall! The draft documents that we recently received from the Secretariat incorporate many of the comments that the Drafting Committee raised in our meeting. We hope that careful consideration of the comments made in this additional iteration on the draft will save time and expedite consensus in the August plenary.

We have reviewed the draft documents as thoroughly as the tight deadline permits and offer both a reworked executive summary and detailed comments on the overview and conclusions. Some of the items in the enclosures reflect concerns about tone or policy implications and will require that substantive revisions be made, while others address typographical or stylistic problems which should improve readability and facilitate discussions in Sundsvall.

As you know, these documents will be used by ministers and heads of state to establish global policy on climate change and therefore they must be clear and convincing and flow logically for the lay reader. As I am sure you also realize, the documents still suffer from some redundancies and organizational problems, in large part a consequence of the Geneva additions and changes. In addition, the documents generally could use a thorough English-languange editing to sharpen the meaning, improve readability, and avoid problems in translation. To try to assist in this editorial process, we have offered extensive suggested revisions in the enclosures.

The primary purpose of this letter, however, is to highlight our key concerns and suggestions which warrant your attention. It is essential that the plenary documents clearly distinguish between what is known and what is projected or hypothesized. This was

the task mandated to the IPCC. The three Working Groups have labored to strike a balance; that balance must be reflected in the plenary reports.

EXECUTIVE SUMMARY

The executive summary must contain a careful statement acknowledging the significant uncertainties inherent in the underlying science. Our reworked executive summary contains the following statement regarding uncertainties, taken from page 2 of the WG I Policymakers Summary:

> There are many uncertainties in our predictions particularly with regard to the timing, magnitude and regional patterns of climate change, due to our incomplete understanding of the sources and sinks of greenhouse gases, clouds, oceans, and polar ice sheets.

The executive summary must strike a balance in its treatment of observed warming over the past 100 years and of the predicted warming. This can be accomplished by including the statement contained in the WG I Policymakers Summary (p. 30, last paragraph), as follows:

> The size of the warming over the last century is broadly consistent with the predictions of climate models, but is also the same magnitude as natural climate variability. If the sole cause of the observed warming were the human-made greenhouse effect, then the implied climate sensitivity would be near the lower end of the range inferred from the models. The observed increase could be largely due to natural variability; alternatively this variability and other human-made factors could have offset a still larger human-made greenhouse warming.

There must be a more balanced presentation in the science summary of natural versus anthropogenic fluxes of greenhouse gases, notably CO2. As I mentioned in Geneva, we should not be afraid to place the entire story before the reader, especially since it may become essential to consider what steps might be taken to modify the "natural" CO2 cycle, should the situation turn out to be more serious even than we now expect. This can be done by including the following short paragraph:

> While the annual anthropogenic emissions of carbon dioxide are only about 4 percent of the total annual exchange of carbon dioxide by natural processes, they have been large enough to modify significantly the natural balance since pre-industrial times. Stabilization of atmospheric carbon dioxide concentrations can be achieved by either a 60-80% reduction in anthropogenic emissions, or an increase in natural sinks by 2-3%.

OVERVIEW AND CONCLUSIONS

Scenarios

The Emission Scenarios A-D should be defined in a separate section at the beginning of the document. The explanation of how they were formulated should be taken from the WG III Policymakers Summary, Section 3.1. For example, for Scenario A:

> Scenario A assumes that few or no steps are taken to limit greenhouse gas emissions. Energy use and clearing of tropical forest and the amount of biomass per hectare are low and fossil fuels, in particular coal, remain the world's primary energy source. The Montreal Protocol comes into effect but without strengthening and with less than 100 percent compliance. Under this scenario, the equivalent of a doubling of pre-industrial CO2 levels occurs, according to WG I, by around 2025.

The Business-as-Usual Scenario should be called Scenario A. At a minimum the designation should be "Scenario A (Business as Usual)."

Similarly, the Reference Scenario should be explained with regard to its purpose, with clarification that it is a scenario and not a plan, and reference made to the data on which it is based. The language should be drawn from the WG III Policymakers Summary, section 3.2.

Greenhouse Gases

This draft continues to focus on CO2 to the virtual exclusion of other greenhouse gases, notably methane, so that the reader is left with the impression that CO2 reduction on the anthropogenic side, and reforestation on the natural side, are the only real options to consider. This does not reflect the conclusions of the AFOS report of WG III. To balance the presentation, lines 21 through 34 on page 17 need to be replaced with the following:

> Because the sources of other greenhouse gases, most notably methane, but also including nitrous oxide and ozone, are diverse and the quantitative importance of each of their sources is not well known at present, emissions reductions may prove difficult to achieve and the effectiveness of different control strategies may be hard to evaluate.
>
> Methane emissions arise primarily from agricultural, energy and waste management activities. Control strategies may include improved agricultural practices; use of low-emitting rice strains; and prevention, or recapture for energy recovery, of emissions from mine shafts, pipelines, and landfills.

Natural Sources and Sinks of Greenhouse Gases

As stated earlier, the document must more explicitly discuss the natural sources and sinks of carbon dioxide, and uncertainties associated with the anthropogenic fluxes. The section (page 4, lines 22 to 30) needs to be expanded. This can most easily be accomplished by using Figure 1 (carbon cycle) on page 8 from Section 1 of the IPCC WG I scientific assessment, and the following text:

> The anthropogenic flux of carbon dioxide is about 6 Gt C per year from the combustion of fossil fuels, plus an additional 0.6 - 2.5 Gt C per year associated with tropical deforestation and changing land-use. These fluxes are much smaller than the natural exchange fluxes (about 200 Gt C per year) which occur between the atmosphere and the terrestrial biota and between the atmosphere and the oceans (Figure I). However, while the anthropogenic fluxes are much smaller than the natural fluxes, they have been large enough to modify significantly the natural balance since pre-industrial times. [Footnote: Scientific evidence for the anthropogenic character of these changes is noted in the Policymakers Summary of Working Group I. (Cite proper page and paragraph.)] Stabilization of atmospheric carbon dioxide can be achieved by a 60-80% decrease in the anthropogenic emissions of carbon dioxide or by an increase of about 2-3% in the natural sinks of carbon dioxide.

Comprehensive Approach

There must be further mention of the comprehensive approach to any possible solutions to the greenhouse gas problem. All greenhouse gases whose atmospheric concentrations are increasing should be considered together. This can be done through the concept of greenhouse warming potentials (GWPs). A short section, such as the following, needs to be inserted on page 15 line 35:

> All greenhouse gases whose atmospheric concentrations are increasing because of human activities contribute to the enhanced greenhouse effect. Therefore, in view of the interrelationship among all greenhouse gases, their sources and sinks, when considering approaches to limit anthropogenic increases in radiative forcing it is essential to take a comprehensive approach to reductions in greenhouse gas emissions, i.e., all gases should be treated collectively (carbon dioxide, methane, nitrous oxide, CFCs, HCFCs, HFC, and ozone and its precursors). To evaluate possible policy options, it is useful to know the relative radiative effect (and, hence potential climate effect) of equal emissions of each of the greenhouse gases. Working Group I developed the concept of relative global warming

potentials (GWPs) which take into account the differing times that gases remain in the atmosphere. Table x lists the GWPs for several key greenhouse gases, together with their 1990 emissions. (Table at the bottom of page 18 of WG I Policymakers Summary should be added here.)

In addition, the following short paragraph needs to be added to the legal issues summary immediately after the last bullet on page 28:

While it is recognized that the Convention is to be all-encompassing, the negotiating parties will have to decide whether greenhouse gases, their sources and sinks, are to be dealt with individually, in groups, or comprehensively.

I must stress that a considered response to these matters is essential if we are to have any hope of reaching consensus in Sundsvall. Please call if there is anything further that I can do to help, and good luck.

Best regards,

Frederick M. Bernthal

cc: Dr. N. Sundararaman

enclosures:
1) reworked executive summary
2) specific comments on overview and conclusions
(to follow on July 6, 1990)

N A T I O N A L S C I E N C E F O U N D A T I O N

Division of Atmospheric Sciences

MEMORANDUM

DATE: August 7, 1990

TO: AD/GEO

FROM: DIVISION DIRECTOR/ATM

SUBJ: Impact of Amazonian Deforestation

The question has been asked if the deforestation of the Amazon would/could have an effect on global weather. There is no clear cut answer, yes or nor; however, there has been some research done on facets of that issue.

In the March 16, 1990 issue of Science magazine there was an article entitled "Amazon Deforestation and Climate Change" by J. Shukla (University of Maryland), C. Nobra (Instituto de Pasquisas Espaciais of Brazil), and P. Sellers (University of Maryland). These researchers used a coupled atmospheric/biospheric model to assess the effects of deforestation of the Amazon on global and regional climate.

The results from the simulation of a deforested Amazon as compared with the forested case are as follows:

* The degraded pasture cover has a higher albedo, lower surface roughness length, higher stomatal resistance, a shallower and sparser root system, and lower available capacity for soil moisture.

* Surface and soil temperatures are warmer.

* Evapotranspiration is reduced.

* Absorbed solar energy at the surface is reduced.

* Amount of net radiative energy available at the surface

for participation into latent and sensible heat flux is considerably smaller

* Less precipitation is intercepted and reevaporated at the surface.

* Canopy-water holding capacity of the pasture is small.

The net result is that the forested area is replaced by a pasture environment. Results suggest that a complete and rapid destruction of the Amazon tropical forest could be irreversible.

The simulations indicate impacts beyond the Amazon itself, especially in the area in which precipitation is reduced.

Similar research has been reported by Lean and Warrilow of the UK Meteorological Office suggesting that rainfall would be reduced by 20%. The National Center for Atmospheric Research (NCAR) has a coupled Biosphere-Atmosphere Transfer Scheme that is being used to look at deforestation simulations of the Amazon region.

The University of Maryland group has expanded their simulations to look at global impacts. Their results have not been published, but there are trends that indicate that there are global impacts on the climate and therefore undoubtedly on global weather. Nevertheless, there are no observational nor simulated data to support that assertion.

To complicate the issue further, a recent article in The Washington Post on July 29, 1990 indicates that there is a possibility that much of the new CO_2 entering the atmosphere is coming from plants themselves. The research seems to indicate that the hotter the planet gets the more plants will respire and emit CO_2 into the atmosphere. Apparently this finding is a controversial one that is not accepted completely by the biological/ecological community.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR GEOSCIENCES

August 13, 1990

Dr. John P. McTague
Vice President for Technical Affairs
Ford Motor Company
American Road
Dearborn, MI 48121-1899

Dear John:

It was a pleasure to see you again at the most recent PCAST Meeting and to chat shortly thereafter. Thank you for your interest in the environmental side of the PCAST agenda.

I am enclosing a series of materials that begin to address the non-carbon side of the Amazonian issue. My discussions with our NSF staff in the Atmospheric Sciences suggest that there are serious scientific questions that need to be understood. The enclosed indicates, I think, the sketchy nature of our state of knowledge. After you have had a chance to review it, maybe we could talk a bit more.

Sincerely,

Robert W. Corell
Assistant Director

Enclosures

cation as a template by examining the interior volume defined by the channel and pocket features of the ZSM-18 structure. A slice of the unit cell between $z = 0$ and $z = 1/2$ can be viewed along the c axis to outline the largest interior volume projection. Since the structure of the triquat cation is known (*2*, *3*), it can be drawn to scale within that volume. A stereo drawing of the triquat cation and the proposed locations of the triply charged ions within the ZSM-18 structure are shown in Fig. 4. The scaled projection drawing shows that the triquat moiety must occupy rather specific positions within the framework structure of ZSM-18. The probable arrangements of aluminosilicate anions and organic cations that would favor cocrystallization make it less surprising that a 3-ring of aluminosilicate material could form to balance the positively charged triquat. Clearly, this suggests, however, that the formation of ZSM-18 and perhaps any 3-ring aluminosilicate zeolite may depend on the judicious choice of a bulky, multiply charged, cationic templating species.

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5. The International Zeolite Association designation for secondary building units (SBU) for these structures requires the introduction of a new SBU, the single 3-ring, in order to describe them. For models A and B, the SBU requirements are a single 3-ring + 6≡1, where the symbol 6≡1 refers to a capped 6-ring.
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$$R_w = \left\{ \sum_{(m,n)_j} [w_j(D_j^{m,n} - D_j^{m,n})]^2 / \sum_j (w_j D_j^m)^2 \right\}^{1/2}$$

$$\sigma = \left\{ \sum_{(m,n)_j} [w_j(D_j^{m,n} - D_j^{m,n})]^2 / (M - NV) \right\}^{1/2}$$

where w_j are the weights associated with each interatomic distance type j between atoms m and n ($D_j^{m,n}$) (such as T–O, T–T, and O–O), M is the number of distances, and NV is the number of variables. D_j^m are the prescribed distances for each type and are determined by:

$$D^m = A + B(\mathrm{TOT} - \omega) + C(\mathrm{TOT} - \omega)^2 + \ldots,$$

where A, B, and C are constants, TOT is the calculated angle about each O, and ω is the standard T–O–T angle, for example, 145°. In our calculations, $A = 1.61$, $B = -4 \times 10^{-4}$, and $C = 0$.
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16 October 1989; accepted 18 January 1990

Amazon Deforestation and Climate Change

J. SHUKLA, C. NOBRE,* P. SELLERS

A coupled numerical model of the global atmosphere and biosphere has been used t assess the effects of Amazon deforestation on the regional and global climate. Whe the tropical forests in the model were replaced by degraded grass (pasture), there was significant increase in surface temperature and a decrease in evapotranspiration an precipitation over Amazonia. In the simulation, the length of the dry season als increased; such an increase could make reestablishment of the tropical forests afte massive deforestation particularly difficult.

THE DISTRIBUTION OF GLOBAL VEGETATION was traditionally thought to be determined by local climate factors, especially precipitation and radiation. This view has been modified because controlled numerical experiments with complex models of the atmosphere showed that the presence or absence of vegetation can influence the regional climate (*1–3*). One implication of these results is that the current climate and vegetation may coexist in a dynamic equilibrium that could be altered by large perturbations in either of the two components. The high rate of deforestation in the Brazilian portion of Amazonia, from 25,000 to 50,000 km^2 per year (*4–7*), might thus be expected to have an effect on the regional climate. If deforestation were to continue at this rate, most of the Amazonian tropical forests would disappear in 50 to 100 years.

Removal of the Amazonian forest would also have tremendous effects on species diversity and atmospheric chemistry (*8*). The Amazon basin is host to roughly half of the world's species, and the intensity and complexity of plant-animal interactions (*9*) and the rapid nutrient cycling in the soils (*10*) make the region vulnerable to external disturbances. The Amazon is also an important natural sink for ozone and plays an important role in global tropospheric chemistry. The present study is mainly confined to the assessment of the effects of deforestation on the physical climate system.

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Quantitatively estimating the effects th large changes in terrestrial ecosystems c have on temperature, circulation, and rai fall has been difficult because the equilibr um climate is determined by complex inte actions among the dynamical processes the atmosphere and thermodynamic pr cesses at the earth-atmosphere interface. R alistic models of the biosphere that can b coupled with realistic models of the glob atmosphere have only recently been deve oped (*11*, *12*). In this report, we describe th use of a coupled atmosphere-biosphe model (*13*, *14*) to investigate the cons quences of the removal of Amazon fores on climate.

In the simulations, we assumed that th

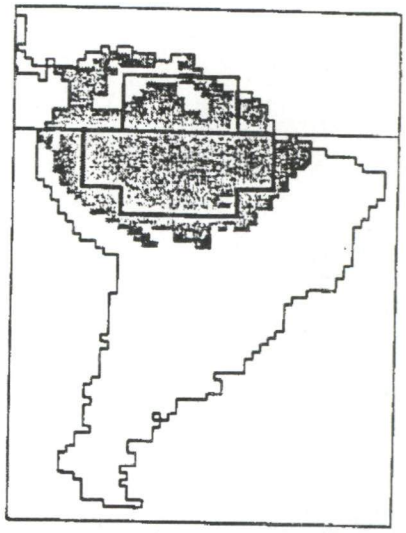

Fig. 1. The South American region. Stippling depicts the area covered by the tropical forest in the control simulation. The area marked with bold lines was used for the areal averages of Fig. 3 and for Tables 1 and 2.

Table 1. Mean surface energy budget. The data are 12-month mean (1 January to 31 December) values. Values are in watts per square meter, except for B an a, which are nondimensional, and T_s, which is in degrees centigrade. S is insolation; a is albedo; L_n is net upward long-wave radiation; R_n is availab radiative energy; E_t is transpiration plus soil evaporation; E_i is interception loss; E is evapotranspiration = $E_t + E_i$; H is sensible heating; G is ground he flux; B is the Bowen ratio (H/E); and T_s is surface temperature.

Case	S	$(1 - a)S$	L_n	R_n	E_t	E_i	E	H	G	B	a	T_s
Control	233	204	−32	172	91	37	128	44	0	0.34	12.5	23.
Deforestation	237	186	−40	146	64	26	90	56	0	0.62	21.6	26.
Difference	+4	−18	−8	−26	−27	−11	−38	+12	0	−0.28	+9.1	+2.

tropical forest cover (Fig. 1) is replaced by a degraded pasture. On the basis of observed changes in soil characteristics in deforested areas (*15, 16*), we also assumed that the soils in the deforested regions are disaggregated and that, as a result, values of the soil hydraulic conductivity and water storage capacity available for transpiration are greatly reduced in the upper part of the soil profile.

We have used a high-resolution global model of the atmospheric circulation (*13*) that describes and predicts atmospheric temperature, pressure, wind, and humidity at 18 different, unequally spaced levels between the surface and 30 km. The horizontal resolution of the model at each level is about 1.8° latitude by 2.8° longitude. The large-scale topography and sea-surface temperature (SST) are prescribed. The diurnal cycle is treated explicitly in the model, and both the convective and the large-scale saturation rainfall are calculated. For radiative calculations, zonally symmetric clouds are prescribed rather than generated by the model. The global vegetation distribution at each land grid point is defined by 1 of 12 vegetation types, and each vegetation type is defined by a set of morphological, physical, and physiological parameters (*17*). There are three soil layers in the biosphere model: a thin evaporating upper layer, the root zone, and a recharge zone.

In the biosphere model (*12, 14*), the wind speed, air temperature, incident radiative flux, and precipitation as calculated from the atmospheric model are used to predict the time rate of change of the model variables: canopy temperature; ground temperature; deep soil temperature; liquid water stored on canopy foliage and ground cover foliage; and the wetness of the surface thin layer, root zone, and recharge zone. Runoff, soil moisture, and sensible and latent heat fluxes are calculated as diagnostic outputs of the model.

We first integrated the coupled atmosphere-biosphere model for 1 year with the normal prescribed global climatological boundary conditions of vegetation distribution, in which the Amazonian region is covered with tropical forests (Fig. 1); we refer to this integration as the control case. We then repeated the integrations for 1 year in which all the previous global climatological boundary conditions remained the same except over Amazonia, where the tropical forests were replaced by a degraded pasture cover consisting mainly of grass; we refer to this integration as the deforestation case. In both the control and the deforestation cases, the global SST distributions remained inadvertently fixed for the whole integration period and corresponded to the climatological mean values for December.

The changes over Amazonia in the deforestation case, in effect, resulted in the alteration of a series of climatologically significant parameters. Relative to the tropical forest, the degraded pasture cover is calculated to have a higher albedo, lower surface roughness length, higher stomatal resistance, a shallower and sparser root system, and lower available storage capacity for so moisture. The parameters for the contro case were obtained from a literature surve and from an analysis of 2 years of in situ flu measurements (*18*), whereas the parameter for the deforestation case were extracte from reports on fieldwork carried out i deforested areas (*16, 19, 20*).

The model integrations were started fron an atmospheric state on 15 December, whe the initial soil moisture in the region coul be assumed to be at or near saturation i both cases, and integrations were carried ou for 12.5 months. The results (Fig. 2) are i terms of 12-month averages (1 January t 31 December); the first 2 weeks of mode integration are ignored. The annual cycle o temperature, precipitation, and evapotran spiration are shown as monthly averages.

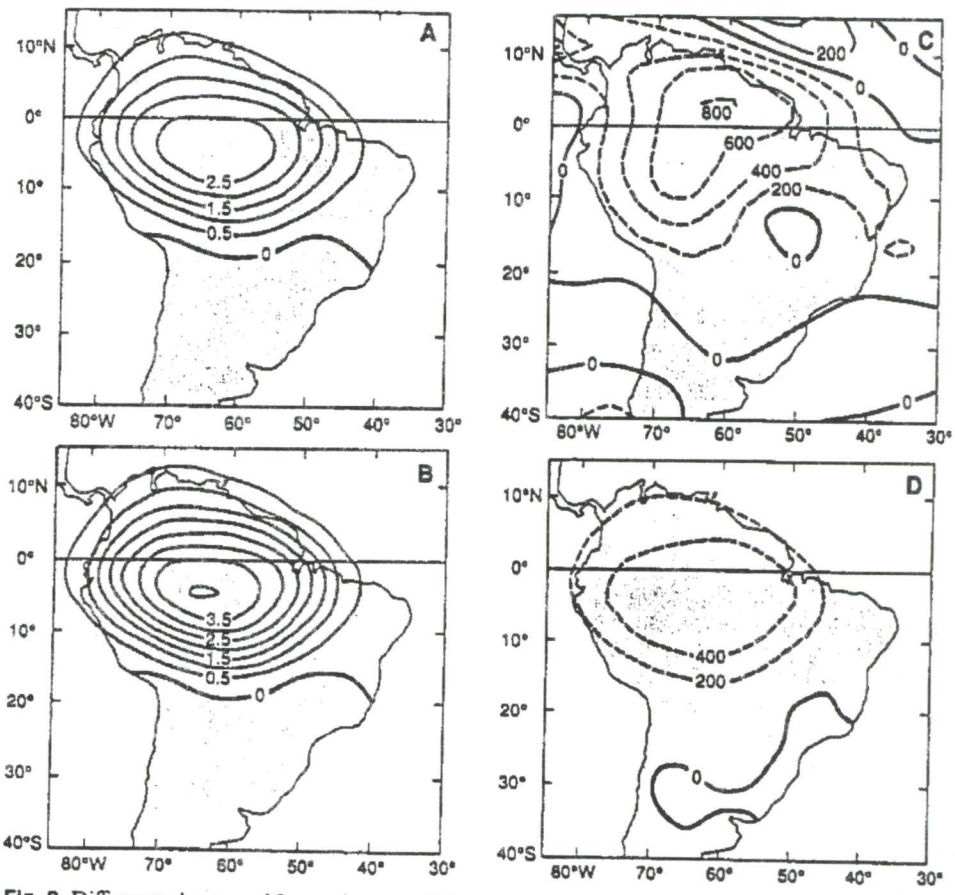

Fig. 2. Differences between 12-month means (1 January to 31 December) of deforestation and control cases (deforested − control) for the South American sector: (**A**) surface temperature increase in degrees centigrade; (**B**) deep soil temperature increase in degrees centigrade; (**C**) total precipitation changes (dashed lines indicate a decrease) in millimeters; and (**D**) evapotranspiration decrease in millimeters. Model results were smoothed before plotting.

Surface and soil temperatures are warmer by 1° to 3°C in the deforestation than in the control cases. The relative warming of the deforested land surface and the overlying air is consistent with the reduction in evapotranspiration and the lower surface roughness length. This result is in agreement with results of an earlier simulation experiment (*21*) and some observations (*22, 23*) for tropical forests.

The increase in surface temperature calculated in the deforestation case is reflected in differences in the surface energy budget for the two cases (Table 1). The absorbed solar radiation at the surface is reduced in the deforestation case (186 W/m^2) relative to the control case (204 W/m^2) because of the higher albedo (21.6%) for grassland compared to forest (12.5%). The higher surface temperature in the deforestation case gives rise to more outgoing long-wave radiation from the surface compared to the control case, so that the amount of net radiative energy available at the surface for partition into latent and sensible heat flux is considerably smaller in the deforestation case. In addition, the reduced storage capacity for soil moisture in the deforestation case has the effect of reducing the time-averaged transpiration rate; also, in the deforestation case, less precipitation is intercepted and reevaporated as the surface roughness and the canopy–water holding capacity of the pasture are relatively small.

Table 2. Mean water budget. The data are 12-month mean (1 January to 31 December) values. Values of E and P are in millimeters per year; PW is in millimeters. P is total precipitation; E is evapotranspiration; and PW is precipitable water.

Case	P	E	$(E - P)$	E/P	PW
Control	2464	1657	−807	0.67	37.7
Deforestation	1821	1161	−660	0.63	35.4
Difference	−643	−496	+147	−0.04	−2.3
		Change (in percent)			
	−26.1	−30.0	+18.0	−5.9	−6.1

The reduction in calculated annual precipitation by 642 mm and in evapotranspiration by 496 mm (Table 2) suggests that changes in the atmospheric circulation may act to further reduce the convergence of moisture flux in the region, a result that could not have been anticipated without the use of a dynamical model of the atmosphere. Increased surface and soil temperatures produce some increase in the sensible heat flux (about 10 to 20 W/m^2, not shown); however, even the increased warming of the near-surface air is not sufficient to increase the convergence of air (and moisture) into the region in the simulation.

Because evapotranspiration from the forest is one of the important sources of water vapor (*24, 25*) for precipitation in the Amazon, a reduction in evapotranspiration is expected to lead to a reduction in precipitation. However, because of the complexity of the atmosphere-biosphere system and the continuous interactions of dynamical and hydrological processes, a reduction in evaporation might be compensated for by an increase in moisture flux convergence. Our experiments indicate that such a compensation will not occur for the Amazon and that there is even a further decrease in convergence of the large-scale moisture flux. Whether this result is model-dependent can only be resolved by additional experiments and comparison with results from other models.

The differences in monthly mean surface temperature, precipitation, evapotranspiration, and evapotranspiration minus precipitation for the control and the deforestation cases are consistently of the same sign but of different magnitude for each of the individual months (Fig. 3). This consistency is partly a result of the large area for spatial averaging; similar time series for different, smaller subregions of the Amazon will show more variability from one season to the other. The value of evapotranspiration minus precipitation increased in the deforestation simulation. Runoff was also reduced in the deforestation case because the decrease in precipitation was more than the decrease in evapotranspiration.

A few significant changes in global circulation were also evident in the deforestation simulation, especially over North America; however, climatic fluctuations over the northern mid-latitudes are generally large in nature as well as in simulations even without any forced perturbations, and thus the anomalies may not be directly a result of the deforestation simulation. Moreover, the artificial constraint of time-invariant SST

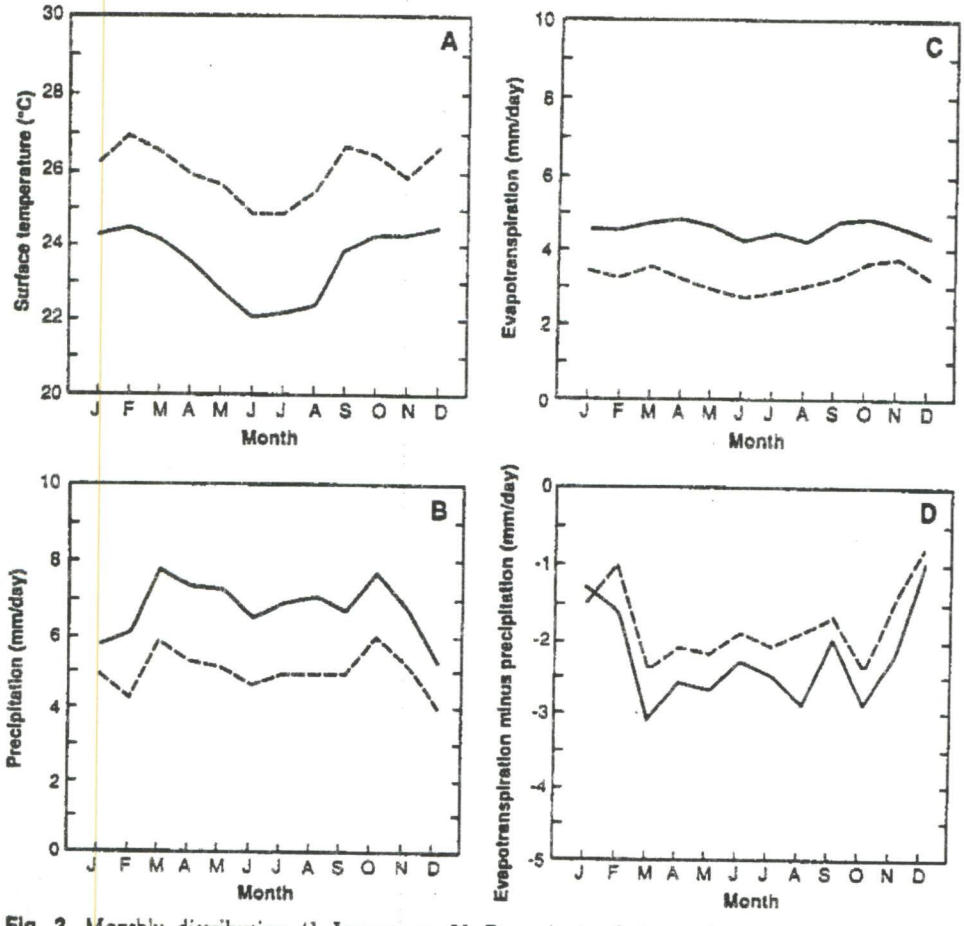

Fig. 3. Monthly distribution (1 January to 31 December) of the areal average of (**A**) surface temperature; (**B**) total precipitation; (**C**) evapotranspiration; and (**D**) evapotranspiration minus total precipitation. The solid line is for the control case, and the dashed line is for the deforestation case. Areal averages were taken over the area marked with bold lines in Fig. 1.

fields makes it difficult to draw any definitive conclusions about the global effects of Amazon deforestation from this study.

The most significant result of this study is the simulated reduction in precipitation over Amazonia, which is larger than the corresponding regional reduction in evapotranspiration, implying that the dynamical convergence of moisture flux also decreased as a result of deforestation. The spatial and temporal coherence of the decrease in precipitation implies that the deforested case is associated with a longer dry season. The lack of an extended dry season apparently sustains the current tropical forests, and therefore a lengthening of the dry season could have serious ecological implications (*26–28*). Among other effects, the frequency and intensity of forest fires could increase significantly (*29, 30*) and the life cycles of pollination vectors could be perturbed.

These results suggest that a complete and rapid destruction of the Amazon tropical forest could be irreversible. Changes in the region's hydrological cycle and the disruption of complex plant-animal relations could be so profound that, once the tropical forests were destroyed, they might not be able to reestablish themselves.

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31. We thank J. Kinter, L. Marx, M. Fennessy, Schneider for help in conducting this sim experiment, P. Dirmeyer for help in the pro and diagnosis of model outputs, and A. D. for providing information about the Ama ecosystem. We also thank S. Busching for help preparation of the manuscript and L. Rumbt drafting the final figures. This research was su ed by National Science Foundation grant AT 13567 and National Aeronautics and Space A istration grants NAGW-1269 and NAGW-55

13 October 1989; accepted 14 December 19

Fossil Soils and Grasses of a Middle Miocene East African Grassland

GREGORY J. RETALLACK, D. P. DUGAS, E. A. BESTLAND

Fossil soils and grasses from the well-known Miocene mammal locality of Fort Tern southwestern Kenya, are evidence of a mosaic of grassy woodland and wooc grassland some 14 million years ago. This most ancient wooded grassland yet kno on the African continent supported more abundant and diverse antelopes than kno earlier in Africa. Ape fossils at Fort Ternan, including *Kenyapithecus wickeri*, w associated with woodland parts of the vegetation mosaic revealed by paleosc Grassland habitats were available in East Africa long before the evolutionary div gence of apes and humans some 5 to 10 million years ago.

SAVANNA ECOSYSTEMS HAVE LONG been linked with early human evolution, and the antiquity of savannas in Africa has been a source of debate (*1*). Part of the problem is the loose use of the term "savanna" to include any kind of tropical grassland. We prefer the term "wooded grassland" for well-drained grassy vegetation with 10 to 40% cover by trees (*2*). Unlike wooded and open grassland, grassy woodland and marsh are at least as old as 23 million years and remained widespread 17 million years ago in East Africa, judging from evidence of paleosols (*3*), of fossil sedges and grasses (*4*), of fossil dicots (*5*), and of fossil birds allied to modern forms now found widely in grassy vegetation (*6*). Of more interest from the point of view of the evolution of African mammals is the origin of wooded grassland and open grassland among more ancient kinds of woodland and forest vegetation.

Paleosols can be useful in deciphering ancient vegetation mosaics, because, unlike fossils, they are by definition in the place they formed. They are also abundant and have been widely recognized in southwest Kenya (*3, 7–9*). The thin, brown, nodul calcareous paleosols found throughout t 9.6-km outcrop of the middle Miocene Fc Ternan Beds are distinct from geologica older paleosols in Kenya (*3, 10*). The Fc Ternan beds are a sequence of carbonatit nephelinite tuffs, lahars, colluvium, and all vium. They have been dated by the K/ method at 14.4 ± 0.2 million years old b the use of biotite (*7, 11*). This accour details only paleosols in the 8-m-thick s quence exposed in the large (*12*) quarry fc fossils at Fort Ternan National Monumen Three distinct kinds of paleosols were recog nized and named informally from the loca Dholuo language: Chogo ("bone"), Onuri ("yellow"), and Dhero ("thin") paleosol se ries. The paleosols were characterized in the field, petrographically, and chemically (*13*) From these data (Fig. 1), some aspects of the original soils and their environment can be reconstructed.

One approach to interpreting paleosols is to identify them within a soil classification and compare them to modern soils, with allowance for possible alteration after burial. The distinctive surface horizons of both Onuria and Chogo paleosols are critical to their identification: they have the granular structure, thickness, dark color, and large proportion of bases that define a mollic epipedon and Mollisols (*14*). Organic mat-

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OUTPOSTS

Revenge of the Killer Trees

Is World Vegetation Becoming a Giant Carbon-Dioxide Pump?

By Curtis Moore

SOME SCIENTISTS and politicians—including George Bush—increasingly view plants as a sort of Noah's Ark in which humanity can ride out the storm of global warming. But a flood of recent evidence suggests that plants and soils might prove instruments of destruction, not salvation.

Consider the following:

- Two increases—one certain, the other less so—in the rate of increase of carbon dioxide in the past 15 years, almost as if a second CO2 faucet had been turned on in 1976, then possibly a third in 1987. Probable cause: plants.
- Discrepancies in atmospheric makeup which can be best explained by the existence of a "positive feedback" system involving CO2, a major greenhouse gas. That is: The hotter it gets, the hotter it *will* get. Probable cause: plants.
- Unexplained, but large and abrupt increases in concentrations of methane—40 percent since the 1950s, which is lightning speed for the global environment—perhaps from the same source as the CO2, but perhaps not. A likely cause: plants.
- Recent direct evidence that much of the new CO2 entering the air emanates from the last place most people would expect it: plants.

One distressing possibility is that the record heat of the 1980s—the warmest decade in recorded history—helped trigger the recent rise in global CO2 by boosting the rate at which plants and microorganisms "respire," or extract energy from stored foods.

"The implication we assign to these observations," says George Woodwell of the Woods Hole Research Institute, "is that the surge [in CO2] is the result of the high temperatures of the 1980s, delayed by the time necessary to warm the soil."

The mean green hypothesis may prove incorrect. But it underscores the threat of "surprises" that almost certainly lie hidden in the bewildering complex of interactions subsumed under the simple label "global warming."

If asked to find evidence of warming, the average person might simply look at annual temperature records to see whether there has been a regular linear rise. But that could be the wrong thing to look for. In many cases, natural reactions are neither smooth nor predictable, particularly in "threshold" situations: Water, heated past a critical point, turns to steam rather than hotter water; avalanches topple all at once instead of in a series of gentle slides; lightning suddenly shatters the air—all when a threshold is crossed. This can happen in the environment. The Antarctic ozone hole is precisely that sort of runaway reaction—one that no scientist predicted despite tens of millions of dollars spent on research.

Curtis Moore, who served for 11 years as counsel to the Senate Committee on Environment and Public Works, is an environmental analyst and writer.

It is the possibility of such "surprises"—a euphemism scientists prefer—that cause some experts to conclude that if you don't know what's on the other end of the rope, quit jerking.

How the Planet Breathes

Plants consume carbon dioxide through photosynthesis. But they and soil microorganisms such as bacteria also give off CO2 through "respiration."

In photosynthesis, a plant converts the energy of sunlight into a chemical form that is used to transform carbon dioxide into carbohydrates, usually molecules of sugar or starch. In respiration, the molecular bonds are, in effect, cracked in a complex, three-step process which releases small increments of energy. It is used to build new tissue, grow flowers or perform other useful work. Carbon dioxide and water are the waste byproducts, discarded by animals through their lungs and plants through their leaves.

In young and mature plants under normal circumstances, the amount of carbon fixed by photosynthesis is greater than or equal to the quantity released through respiration. Heat skews that system, accelerating the rates of both. As temperature climbs, the rate of photosynthesis peaks, then begins dropping. In contrast, the respiration rate—and thus the amount of CO2 generated—continues to rise. As a general rule, respiration doubles for every 18° F increase in temperature. In almost all cases, this process does not require light, and is thus called "dark" respiration.

"Raise the temperature and dark respiration will increase exponentially," says W. Dwight Billings, a Duke University specialist in arctic and mountain plant systems, "right up the point where everything dies." He estimates that two-thirds of the land's carbon is stored in soil where plants and microorganisms can release it as carbon dioxide or methane, another global warming gas. A significant global temperature increase would mean that "respiration rates will increase more than photosynthesis," according to Woodwell.

The Mean Green Machine

There is no dispute whatsoever that CO2 concentrations in the Earth's air have been rising steadily—up 12 percent in the past 30 years. But twice—once in 1976, then again in 1987—the speed with which CO2 was building up jumped sharply, just as Woodwell's theory would suggest. It is possible that these jumps were due to El Nino cycles or major underestimates of the extent of tropical deforestation. But in either of those cases, the increases should have been temporary. Instead, they've persisted.

But is this CO2 from plants? Evidence collected by Charles D. Keeling of the Scripps Oceanographic Institute suggests that it is.

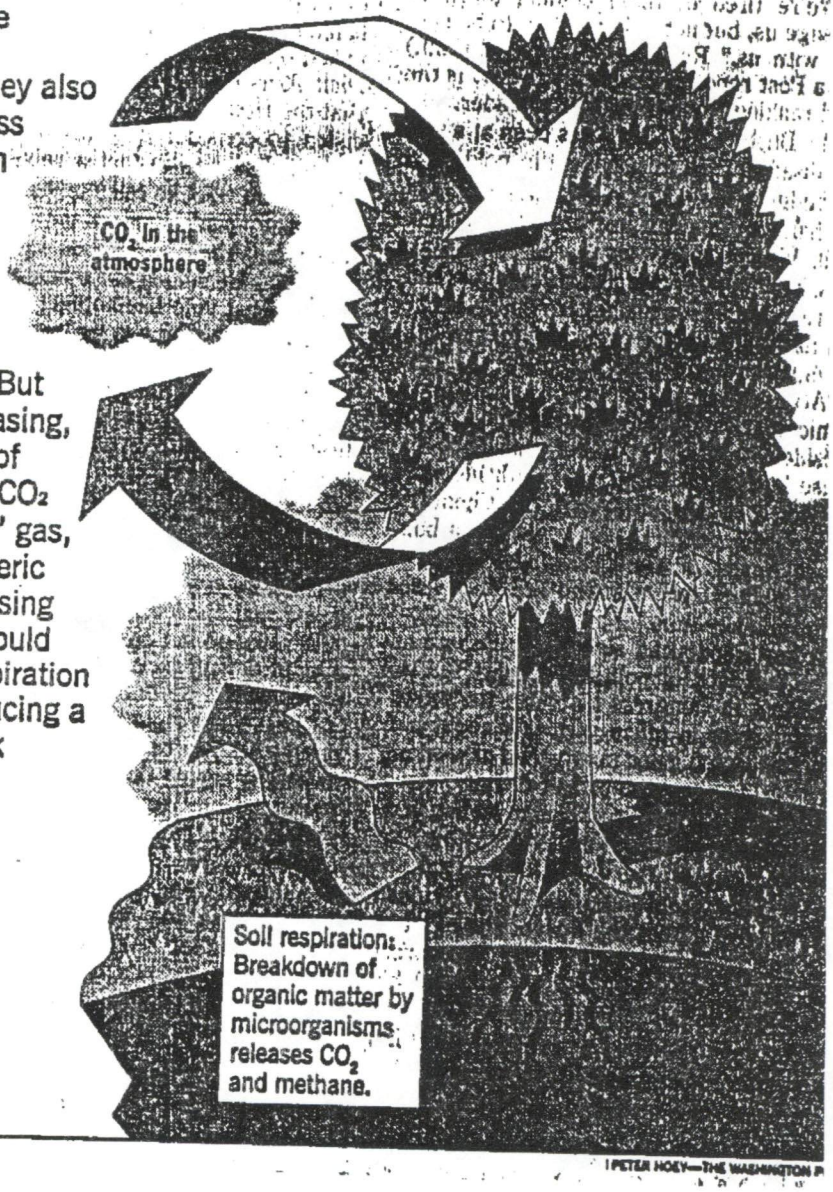
THE WASHINGTON POST

SUNDAY, JULY 29, 199

ENVIRONME

PLANTS AND THE VICIOUS CARBON CYCLE

Plants take in carbon dioxide through the familiar action of photosynthesis. But they also give off CO_2 in a process called respiration. Both photosynthesis and respiration tend to increase as the temperature rises. After a certain point, photosynthesis peaks. But respiration keeps increasing, driving up the amount of CO_2 released. Because CO_2 is a major "greenhouse" gas, it could cause atmospheric temperatures to rise. Rising temperature, in turn, would increase the rate of respiration in plants and soil–producing a self-reinforcing feedback system.



PETER HOEY—THE WASHINGTON P

Clouds. A recent report by the Marshall Institute states: "Clouds cover roughly half the area of the earth at any given time, shielding this area from the sun's rays. As a consequence, they have a cooling effect . . . [but] clouds also have a heating effect because, like greenhouse gases, they block the flow of heat to space from the earth's surface."

Either way, clouds could set up a feedback system, leaving lakes parched or overflowing—or oscillating between the two—as they did in Africa 10,000 years ago as the last glacial period ended. Either would alter CO2 production in the biosphere.

Soils and biological systems. If temperature belts shift, trees, crops and animals could die. Some would be replaced, but many scientists believe that plants will be unable to move as fast as temperature. Billings, for example, dismisses predictions that corn will grow in Siberia and Alaska: "In real life, you're not going to grow Illinois corn on these bleached and acid soils of the Canadian shield. It's highly unlikely over the next 20,000 years. You're just not going to change the soil overnight."

Life in the Feedback Loop

Whether the various anomalies above are examples of runaway feedback reactions or merely a natural and temporary aberrations, they nevertheless point up the unknowns that surround global warming.

Ironically, partisans on both sides of the global-warming debate agree that too little is known. The difference is that one side sees that condition as a basis for business as usual; the other sees it as reason to curb air pollution and energy use.

Responding to criticisms that the massively complex models run by multimillion-dollar "supercomputers" ignore factors ranging from the possible cooling effect of cloud cover to the increased evaporation from oceans, John Firor of the National Center for Atmospheric Research in Boulder, Colo., says: "That's the problem—there's no way that you can promise that you've thought of everything."

"The danger is that so many things are changing at once," says Irving Mintzer of the University of Maryland's Center for Global Change, a policy analysis institute. "The concentrations of trace gases are increasing while the global temperature is rising and the ozone layer is thinning. It's like playing football when the size of the field, the shape of the ball, the number of players and the method of scoring change with every play."

Because we don't understand the nature of all these interactions, says Wallace Broecker of Columbia University, humanity is playing "Russian roulette."

The man who first concluded the CFCs would destroy the ozone layer was F. Sherwood Rowland, also of UC/Irvine. He was also among the first to suggest the crucial role that temperature plays in the Antarctic ozone hole and to predict that similar losses would be found over the North Pole as well. He regards the CO2 data produced by Keeling and others as "significant—and not very comforting."

Of course, Rowland is inclined to understatement.

Reflecting on the many recent atmospheric findings, Rowland recently recalled the day on which he concluded that chemicals were destroying the ozone shield. "There was no moment when I yelled 'Eureka,' " he says. "I just came home one night and told my wife, 'The work is going very well, but it looks like the end of the world.' "

Plants prefer certain of the carbon isotopes over others just as "yuppies" prefer BMWs. Thus, in much the same way that an influx of young professionals into a high-rise condo could be measured by counting the BMWs in the garage, the amount of CO2 from green plants can be determined by counting the isotopes they like. Keeling—who first began measuring CO2 concentrations at the Mauna Loa observatory in Hawaii in 1957—has done just that.

After sorting and counting the different types of carbon, Keeling found increases in the ratio between Carbon-12 (the isotope that plants and microorganisms prefer) and the more rare Carbon-13. The increase began in 1975 and has escalated to the present. By 1988, the volume of this "anomalous" carbon had risen to 20 percent of the world's total industrial emissions—the rough pollution equivalent of two Chinas. What could produce such a massive increase? Keeling is convinced that "the oceans and land are doing something unexpected" and "ominous." We can, he says, "postulate that plants are being stimulated by carbon dioxide." Comparing rates of respiration and photosynthesis, Keeling says, is like "watching two runners, both running faster and faster, but one running faster than the other."

Dwight Billings has tracked the difference in speed between these two "runners," both in his lab and in the frozen Arctic tundra regions, which are his specialty. On one August day, the CO2 output from a given sample of Alaskan soil nearly doubled as the temperature rose from 2° Centigrade (35.6 F) to 6°C. Roughly 80 percent was generated in the top four inches of soil—the depth most susceptible to global warming. As fog moved across the tundra, lowering temperatures, CO2 output dropped, as it did it the early morning hours. But during the mid-afternoon heat, emissions peaked.

To measure the impact that temperature might have on photosynthesis, Billings drilled cores from the tundra—frozen dirt, lichens, moss and small plants included—and shipped them back to Duke. He then monitored their performance at two temperatures: One set of samples was kept at 4°C (39.2 F), the average temperature in the Arctic summer; another set was kept at 8°C, the level often predicted for the Arctic if global warming occurs. The cooler cores consumed about 8 grams of carbon per cubic meter of soil. In the "greenhouse" samples, that rate dropped by 50 percent.

Billings cautioned in 1982 that warming of the tundra climate could change this plant-soil ecosystem from a sink to a source. Yet scant notice has been paid to this or the many other possible positive feedbacks that can nudge a gentle change into a runaway reaction.

Numerous other other natural systems may be susceptible to this same kind of "vicious cycle" phenomenon:

Oceans. Scientists believe—but aren't certain—that over half the CO2 emitted each year is ultimately dissolved in the ocean. But what if that dissolution rate changes because the sea waters become either saturated or warmer (the warmer the water, the less CO2 it can absorb)—or if they're mistaken about where the carbon is stored? That would force more of the gas into the air, where it would in turn accelerate warming.

Also, ocean currents that now run on global racetracks created by temperature differences might suddenly halt or even reverse, according to Wallace Broecker of Columbia University—leaving a frozen wasteland from London to Moscow. Don't laugh—it happened 10,000 or 11,000 years ago.

Doing the Carbon Shuffle

CARBON, THE backbone of life, is the one chemical element common to trees, grass, muscle and every other thing that is or ever was alive, from Jell-O to Jack Daniels. There is as exactly as much carbon on Earth now as there was 5 billion years ago, but it's arranged differently today.

Before life, carbon was stored in rocks. More than 99.9 percent still is. The rest has been converted to a wide variety of compounds by biological action, starting when life first appeared, some 3 billion years ago.

Like money, this converted carbon circulates. Over time, a single carbon atom will "flux" through the air, land and water, existing as a tree trunk, sea shell, ocean sediment, a roving shark, several different bacteria and a trace gas. The two most important carbon-based trace gases from a global-warming perspective are carbon dioxide and methane.

Burning carbon in the presence of oxygen, whether it's by plants, animals, cars or power plants, produces CO2. In the absence of oxygen—in the center of compost heaps, for example—methane, known as natural gas, is generated. Both gases trap heat radiated from the Earth, although methane is about 20 times more powerful than carbon dioxide.

The amount of carbon dioxide in the air seems vanishingly small—only about three parts in 10,000. But that tiny amount, together with other "greenhouse" gases, raise the Earth's temperature by about 33° Centigrade (60° F) above what it otherwise would be.

After 150,000 years of remaining relatively unchanged, the amount of carbon lingering in the air as CO2 began to skyrocket about 1850, climbing by 25 percent between then and now. Virtually all this increase comes from burning coal, oil and natural gas. North Americans, for example, emit about 30,000 pounds of CO2 each year.

So far, around half of this man-made increase has somehow been removed from the air—absorbed by oceans, plants and soils according to processes not fully understood. Far less well understood: How long this vast and multiplex system will continue in its present manner.

—Curtis Moore

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR GEOSCIENCES

September 12, 1990

Dear Dr. Bromley:

Attached are several additional documents that were requested at the meeting with Governor Sununu, and which we discussed on Friday. Attached are:

1. The summary of current understanding and recent developments in the science of global climate change. The summary is several pages long. In addition to the summary, there is a section on the key scientific uncertainties and a section that outlines key talking points on climate change.

2. There is a two page summary of item 1, in a "stand alone" version. This was also the two page attachment that was added to the summary of the US/GCRP, which I forwarded to you yesterday evening.

3. As an added simple document, I have formatted the "Key Talking Points" into a one-pager, in case you have some additional use for it.

There are two remaining unfilled requests from Governor Sununu:

1. A paper on recent work that updates our knowledge concerning the residence times of methane in the atmosphere. This paper, soon to be published, will indicate that the residence times are a little longer than we thought, more like 11 or 12 years. I have asked the author to forward a copy of his manuscript, but I have not received it yet. I will send it to you as soon as it arrives.

2. A summary of the insights gained during the recent "Snowmass" workshop on Earth system modelling, including climate models. The key individuals who could draft this material have been out of the country and have just returned a couple of days ago. We should have something to you in a few days. Sorry for the delay, but it is important to have the basic material developed by the participants in the actual workshop.

Finally, I want to tell you that the support from a number of individuals was critical in preparing these documents. Dr. Berrien Moore and his group at UNH, along with input from Tom Lovejoy, was vital in drafting the Amazon paper. Dr. Shelby Tilford (NASA), Dr. Robert Watson (NASA), and Dr. Michael Hall (NOAA) provided critical insights and materials in preparing the materials on current understanding and recent developments.

cc: N.Maynard

Bob

Climate Change

Current Understanding and Recent Developments

The Climate System:

The Earth's climate is controlled by the input energy from the sun, by the radiative balance of the atmosphere and by internal processes within the climate system. The radiative balance depends upon the input of solar radiation and the atmospheric concentrations of radiatively active trace gases (i.e., greenhouse gases), clouds and aerosols. The Earth's climate is highly variable. The natural ranges of climate variability (e.g., temperature) are characteristically quite large compared to human-induced signals. To predict changes in the climate system requires an understanding of future changes in the atmospheric concentrations of greenhouse gases and aerosols, and the processes that control the response of the climate system to natural and human-influenced changes in the radiation balance.

Contemporary Changes in the Forcing of the Climate System:

Current Understanding: Natural greenhouse gases, primarily water vapor and carbon dioxide, and to a lesser extent, methane, nitrous oxide and ozone, keep the Earth much warmer than it would otherwise be. It is well documented that since the industrial revolution the atmospheric concentrations of carbon dioxide, methane, nitrous oxide and industrially produced chlorofluorocarbons (strong greenhouse gases) have been increasing primarily due to human activities. However, there are many uncertainties concerning the magnitudes of the sources and sinks of these greenhouse gases, hence their residence time in the atmosphere. In particular, the magnitude of the uptake and release of carbon dioxide by the oceans and terrestrial biosphere, and strengths of the individual sources of methane and nitrous oxide are quite uncertain. These uncertainties limit our ability to understand the quantitative consequences of particular emissions control strategies, e.g., it is difficult to relate future emissions of carbon dioxide to growth in its atmospheric concentration. It should be noted, however, that the time taken for atmospheric carbon dioxide to adjust to changes in sources is of the order of 50-200 years, determined by the slow exchange of carbon between surface waters and deeper layers of the ocean and the response of the terrestrial biosphere. Consequently, carbon dioxide emitted into the atmosphere today will influence the atmospheric abundance of carbon dioxide for centuries into the future, and the atmospheric concentration of carbon dioxide will only respond slowly to changes in emission rates.

Recent Developments: The most significant recent scientific development is the suggestion, based on observational data of atmospheric and oceanic carbon dioxide and theoretical models, that the oceans are only a minor sink (possibly only one half of the previously estimated oceanic uptake) for anthropogenic carbon dioxide, and that the most significant sink for anthropogenic carbon dioxide is most likely uptake by extratropical terrestrial ecosystems.

Historic Changes in the Forcing of the Climate System:

Current Understanding: The most reliable information on past atmospheric carbon dioxide and methane concentrations is obtained by the analysis of air trapped in polar ice cores. Analyses of ice cores from Vostock, Antarctica and Greenland have covered a full glacial - interglacial cycle and show a strong correlation between changes in temperature and changes in the atmospheric concentrations of carbon dioxide and methane. However, because of the low (limited by the rate of occlusion) temporal resolution of the ice cores, it is not possible to establish whether changes in temperature initiated changes in carbon dioxide and methane, or vice-versa.

Recent Developments: One time interval of particular interest is that of the Younger Dryas (about 11,000 years ago) where rapid changes in atmospheric temperatures and carbon dioxide concentrations were observed. While there is no rigorous model that can explain the observed carbon dioxide and temperature variations, it has recently been speculated that they are linked to large-scale changes in the interplay between biological, chemical and physical processes in the oceans. Because this mechanism appears to exert a strong influence on natural variability, it may lead to large responses to greenhouse warming. However, the mechanisms for such potential abrupt changes are not well understood.

Predictions of Climate Change:

Current Understanding: Computer-based models of the climate system (often called GCM's) are currently the best available tools to integrate information about changes in the Earth's climate in response to a change in the atmospheric concentrations of trace gases or aerosols, solar activity, or surface albedo. However, it must be recognized that the current GCM's have substantial limitations. In particular, the prediction of global climate change is very sensitive to the treatment of cloud-radiation interactions. Different cloud-radiation parameterizations in GCM models lead to significant differences, up to a factor of three, in the magnitude of the predicted global warming. Predictions of regional climate changes are very uncertain, and are particularly sensitive to the treatment of ocean dynamics and ocean-atmosphere interactions (the exchange of energy and chemicals between the atmosphere and the surface waters, and between the surface waters and the deep oceans), and to the terrestrial vegetation-atmosphere interactions (the transfer of energy and moisture between land surfaces and the atmosphere). In addition to our current lack of understanding of several key processes, today's computer capabilities severely limit the spatial resolution of the GCMs. Consequently, while the current GCMs represent the overall climatology of the present climate system quite well and all predict that the Earth's climate will warm in response to an increase in the atmospheric abundance of greenhouse gases, it is clear that the predictions of the magnitude and timing of climate changes, especially at the regional level, are considerably uncertain. In particular, accurate regional predictions of changes in the mean state and variability of climatic parameters needed to assess the impact of climatic change on agriculture, natural ecosystems, coastal regions and water resources (such as temperature, precipitation, evaporation, soil moisture and the

occurrence of severe storms at sub-continental scales) -- all of central importance to the modeling of economic impacts of global warming -- are not possible at this time. Other potentially important uncertainties concern feedbacks between climate change and biogeochemical cycling, and possible non-linear feedbacks within the climate system, i.e., changes in ocean circulation.

A key question is what do the GCM's predict for future climate changes based on trace gas emission, recognizing that there are significant scientific uncertainties, and assuming that there will be no long-term changes in solar irradiance or atmospheric aerosol concentrations. Rather than discuss a number of complex emission scenarios, it has been traditional in the scientific community to assume that the atmospheric concentrations of carbon dioxide and the other greenhouse gases will continue to increase at a rate such that there will be a radiative equivalent of a carbon dioxide doubling sometime during the middle of the next century. If this occurs then the GCM predictions that are considered to be most likely are: (i) the equilibrium increase in global mean surface temperature should lie between 1.5 and 4.5 degrees centigrade (highly sensitive to modeling the feedback between clouds and climate change; recent models with more sophisticated treatments of clouds have tended to predict temperature changes at the lower end of this range); (ii) between 60 and 80% of the equilibrium warming should be realized at the time of "equivalent doubling" (sensitive to the treatment of ocean circulation); (iii) global mean precipitation should increase; (iv) sea-ice extent should decrease; and (v) the predicted warming in the northern polar winter should be greater than the global mean.

There are some consistent GCM predictions of climate change at the continental scale (but not sub-continental scale) such as: (i) land areas are predicted to warm more rapidly than oceans, and (ii) mid-latitude land masses in the northern hemisphere will warm more than the global mean and be accompanied by a decrease in summer precipitation. These results carry important implications, but must be stated with lower scientific confidence than those presented above.

Observations of Temperature Changes:

The instrumental record of surface temperatures suggests an increase of between 0.3 and 0.6 degrees centigrade since the mid-nineteenth century, with an undetermined, but probably small (less than 0.05 degrees centigrade) artificial component due to urbanization. The observation of a marked retreat of mountain glaciers in all parts of the world since the end of the nineteenth century tends to support the notion that temperatures have increased globally over the last one hundred years. However, temperatures have not increased smoothly with time, nor uniformly throughout the world. Several points should be noted: (i) the majority of the temperature increase occurred before 1940, prior to most of the anthropogenic increase in the atmospheric concentrations of greenhouse gases; (ii) there is little evidence that the continental U.S. has warmed since 1900; (iii) the northern hemisphere cooled between 1940 and the early 1970s, while the southern hemisphere continued to warm, albeit at a very slow rate; (iv) there have been significant differences in regional changes, especially in the northern

hemisphere, since 1950; and (v) from 1975 to 1982 a more general warming occurred, followed by little global warming since 1982. It is important to recognize, however, that coupled ocean-atmosphere GCM's predict a highly variable global warming signal, moreover, substantial regional variations are expected.

Detection of the "Anthropogenic Greenhouse" Signal:

The Earth's climate is inherently variable on all time scales, both regionally and globally. Hence, the challenge is to detect an "anthropogenic greenhouse" signal amidst the natural variability of the system. While it can be stated that the observed global mean temperature increase over the past 100 years is broadly consistent with theoretical predictions of climate change, it should be noted that the implied climate sensitivity of the actual system would then be in the lower one-third to one-half of the range predicted by GCM's. In addition, natural variability of the climate system may be as large as the observed changes to date, hence the observed changes could be wholly attributable to natural variability or possibly natural variability could have masked (due to natural variability causing a decrease in temperatures) a larger "anthropogenic greenhouse" signal. Consequently, the current observations cannot confirm the presence or absence of an "anthropogenic greenhouse" signal. Detection of such a signal will require determining trends in both forcing functions and several climatically important parameters, coupled with a quantified understanding of natural variability, and the use of time-dependent coupled ocean-atmosphere GCMs.

Sea Level:

Although the data are difficult to interpret, the best scientific assessment is that over the past 100 years, sea level has risen at an average rate of rise of 1.0-2.0 mm/yr. The uncertainties are large, but the principal causes of this rise are consistent with the expected thermal expansion of the oceans and the melting of mountain glaciers. Regional values differ considerably from global values and predicting future conditions is even more uncertain. If the global mean surface temperature increases, then sea level is predicted to rise, primarily due to the thermal expansion of the oceans and to a melting of some land-ice. The current predicted range of sea level increase associated with an increase in carbon dioxide and the other greenhouse gases, lies between about 10 and 30 cm, at the time of a radiative equivalent of a carbon dioxide doubling (sometime during the middle of the next century). Accurate predictions remain difficult, and somewhat controversial, because of the predicted increased snow accumulation over the Antarctica.

Ecological Systems:

Biological Productivity: Where temperature is limiting, warming of soils would increase nutrient availability to plants with potential for increased productivity. Increased temperature will affect respiration more than photosynthesis, possibly reducing carbon stored in terrestrial ecosystems resulting in a positive feedback on atmospheric carbon

dioxide concentrations. Higher atmospheric carbon dioxide concentrations can increase photosynthesis with potential increases in net production, but the duration of "carbon dioxide fertilization effects" is unknown. However, while there is some knowledge of the responses of biological production processes to changes in parameters of the physical environment, how these integrate over the life cycle of even one species interacting in a complex of other species is unknown.

Ecosystem Composition: Species will respond differently to changes in temperature, precipitation and atmospheric carbon dioxide, either singly or in some combination. However, exactly what these responses will be is not known. Also unknown are the changes that will occur among species that affect the structure of ecosystems, including plant-animal and plant-microbe interactions as well as insect and fungal pathogens. GCM's predict that global mean surface temperatures may change much more rapidly in response to an increase in greenhouse gases, an order of magnitude or more, than they did during ice age cycles. If this were to occur, some species will not be able to migrate or otherwise adapt to the changing climate and will become extinct. Offsetting this will be the possible genetic differentiation and expansion that might occur as habitat boundaries are altered, with creation of new barriers to reproduction and dissolution of some old barriers. However, extinction is likely to be more frequent than speciation, further decreasing biodiversity.

Marine Ecosystems: The historical record leaves little doubt that global warming will have an impact on marine planktonic organisms. The structure and productivity of marine ecosystems are strongly influenced by ocean circulation and mixing, with such physical parameters tightly linked with climate. In high latitudes, the distribution of sea ice is especially important, both for plankton and marine mammals and birds. In sub-polar and temperate regions, physical, chemical and biological parameters are highly variable and the system behavior consequently unpredictable. Thus, effects of warming or other changes are similarly uncertain. Warming affects vertical mixing and in turn nutrient supply, a major determinant of ocean productivity. Again, while there is considerable knowledge of specific processes and specific parts of the global oceans, the integration of this knowledge is incomplete and significant gaps in understanding exist.

Scientific Research Needed to Reduce Scientific Uncertainties:

To improve our current understanding of: (i) the natural and human-influenced processes that control the Earth's climate, and (ii) the impacts of climate change at the regional scale, will require an internationally coordinated program of space-based and ground-based research. This research program will need to: (i) establish an integrated long-term program of systematic observations of the Earth's system; (ii) improve our understanding of the physical, chemical, biological, geological and social processes that influence the Earth's environment and its responses; and (iii) develop integrated predictive models. In particular, we need to document the natural variability of the Earth's climate, and to improve our understanding and modeling of: (i) cloud-radiation feedbacks; (ii) the exchange of energy between the atmosphere and the surface waters of the ocean, and between the surface and deep waters of the ocean; (iii) the cycling of

carbon and other key elements between the atmosphere, land and oceans; (iv) the exchange of water and energy between land surfaces and the atmosphere; and (v) the current structure and functioning of ecosystems, and their response to changes.

Summary of Areas of Scientific Uncertainty:

1. *Hydrological cycle:* primarily cloud-radiation and land surface-atmosphere interactions. These uncertainties affect the predicted rate (magnitude at a given time) of "climate change".

2. *Role of the oceans:* the exchange of energy between the ocean and the atmosphere, and between the upper layers of the ocean and the deep ocean. These uncertainties affect the predicted rate of climate change, especially at the regional scale.

3. *Trace gases:* quantification of the uptake and release of carbon dioxide by the oceans and terrestrial biosphere, and quantification of the individual sources of methane and nitrous oxide. These uncertainties affect our understanding of how the climate system will be "forced", hence the rate of predicted climate change. These uncertainties also limit the formation of control strategies.

4. *Predictions of regional climate change:* limitations in computer resources (spatial resolution and physical sophistication), coupled with an inadequate understanding of several key processes (e.g., the exchange of water and energy between vegetative surface and the atmosphere) limit the accuracy of regional climate change predictions at the scale required for impact assessments to be performed (sub-continental).

5. *Detection of global change:* trends in a number of climatically important parameters, coupled with a quantified understanding of natural variability, is needed to differentiate between human-induced changes in the environment from those that occur naturally. This will require long-term observations of climatically important parameters and forcing functions, as well as careful development of time-dependent coupled ocean-atmosphere GCM's.

Key Talking Points:

1. The Earth's climate is highly variable. The natural ranges of climate variability (e.g., temperature) are characteristically quite large compared to human-induced signals.

2. Human activities are increasing the atmospheric concentrations of greenhouse gases, but uncertainties about their sources and sinks limit the

formulation of effective control strategies.

3. Computer-based models of the climate system (often called GCM's) are currently the best available tools to integrate information about changing climate conditions. While these models all predict the Earth's temperature will increase in response to an increase in the atmospheric concentrations of greenhouse gases, it must be remembered that there are numerous scientific uncertainties concerning the prediction of the magnitude and timing of climate change, especially at the regional scale. Perfecting these models so that they become true prediction tools is one of the key objectives of the US/GCRP.

4. Observational evidence suggests that the global mean surface temperatures have increased by between 0.3 and 0.6 degrees centigrade within the last one hundred years, but because of natural variability it is not possible to ascertain the cause of the observed increase. The observational record cannot be used to confirm or refute the presence of an "anthropogenic greenhouse" signal.

5. If a global warming were to be caused by increasing atmospheric concentrations of carbon dioxide and other long-lived gases (e.g. CFCs and nitrous oxide) then even with significant reductions in their emissions it would take a very long time, decades to centuries, to reverse the "anthropogenic" warming.

6. Predictions of changes in agriculture and natural ecosystems are not only limited by a lack of reliable regional climate change predictions, but also an inadequate understanding of how biological productivity and ecosystem composition will respond to environmental change.

Climate Change - Summary of Current Understanding and Recent Developments

The Climate System:

The Earth's climate is controlled by the input energy from the sun, by the radiative balance of the atmosphere, and by internal processes within the climate system. The radiative balance depends upon the input of solar radiation and the atmospheric concentrations of radiatively active trace gases (i.e., greenhouse gases), clouds and aerosols. To predict changes in the climate system requires an understanding of future changes in the atmospheric concentrations of greenhouse gases and aerosols, and the processes that control the response of the climate system to natural and human-influenced changes in the radiation balance.

Contemporary Changes in the Forcing of the Climate System:

Current Understanding: Natural greenhouse gases, primarily water vapor and carbon dioxide, and to a lesser extent, methane, nitrous oxide and ozone, keep the Earth much warmer than it would otherwise be. It is well documented that since the industrial revolution the atmospheric concentrations of carbon dioxide, methane, nitrous oxide and industrially produced chlorofluorocarbons (strong greenhouse gases) have been increasing primarily due to human activities. However, there are many uncertainties concerning the magnitudes of the sources and sinks of these greenhouse gases. The time atmospheric carbon dioxide takes to adjust to changes in sources is of the order of 50-200 years, hence, carbon dioxide emitted into the atmosphere today will influence the atmospheric abundance of carbon dioxide for centuries into the future.

Recent Developments: The most significant recent scientific development is the suggestion that the oceans are only a minor sink (possibly only one half of the previously estimated oceanic uptake) for anthropogenic carbon dioxide, and that the most significant sink for anthropogenic carbon dioxide is most likely uptake by extratropical terrestrial ecosystems.

Historic Changes in the Forcing of the Climate System:

Current Understanding: The most reliable information on past atmospheric carbon dioxide and methane concentrations is obtained by the analysis of air trapped in polar ice cores, which shows a strong correlation between changes in temperature and changes in the atmospheric concentrations of carbon dioxide and methane.

Recent Developments: About 11,000 years ago, rapid changes in atmospheric temperatures and carbon dioxide concentrations were observed (a period known as the Younger Dryas). Recently, it has been suggested that these changes are linked to abrupt and large-scale changes in the interplay between biological, chemical and physical processes in the oceans.

Predictions of Climate Change:

Current Understanding: General Circulation Models (GCM's) are currently the best available tools with which to predict changes in the Earth's climate in response to a change in the atmospheric concentrations of trace gases or aerosols, solar activity, or surface albedo. The current GCM's have substantial limitations, in particular, they are very sensitive to the treatment of cloud-radiation interactions. Different cloud-radiation models lead to significant differences (up to a factor of 3) in the magnitude of the predicted global warming. Predictions of regional climate changes are very uncertain. They are particularly sensitive to the treatment of ocean dynamics and ocean-atmosphere interactions and to the terrestrial vegetation-atmosphere interactions. Further, current computer capabilities severely limit the spatial resolution of the GCMs. Therefore, the predictions of the magnitude and timing of climate changes, especially at the regional level, are considerably uncertain. However, given these limitations, GCM's suggest that: (i) the equilibrium increase in global mean surface temperature should lie between 1.5 and 4.5 degrees centigrade; (ii) between 60 and 80% of the equilibrium warming should be realized at the time of "equivalent doubling"; (iii) global mean precipitation should increase; (iv) sea-ice extent should decrease; and (v) the predicted warming in the northern polar winter should be greater than the global mean.

Observations of Temperature Changes:

The instrumental record of surface temperatures suggests an increase of between 0.3 and 0.6 degrees centigrade since the mid-nineteenth century, with an undetermined, but probably small (less than 0.05 degrees centigrade) artificial component due to urbanization. Temperatures have not increased smoothly with time, nor uniformly throughout the world, i.e., (i) the majority of the temperature increase occurred before 1940, prior to most of the anthropogenic increase in the atmospheric concentrations of greenhouse gases; (ii) there is little evidence that the continental U.S. has warmed since 1900; (iii) the northern hemisphere cooled between 1940 and the early 1970s, while the southern hemisphere continued to warm; (iv) there have been significant differences in regional changes, especially in the northern hemisphere, since 1950; and (v) from 1975 to 1982 a more general warming occurred, followed by little global warming since 1982.

Detection of the "Anthropogenic Greenhouse" Signal:

The Earth's climate is inherently variable on all time scales, both regionally and globally. The challenge is to detect an "anthropogenic greenhouse" signal amidst the natural variability of the system. Current GCM's and observations cannot confirm the presence or absence of an "anthropogenic greenhouse" signal.

Sea Level:

Although the data are difficult to interpret, the best scientific assessment is that over the past 100 years, sea level has risen at an average rate of rise of 1.0-2.0 mm/yr. The uncertainties are large, but the principal causes of this rise are consistent with the expected thermal expansion of the oceans and the melting of mountain glaciers. Regional values differ considerably from global values and predicting future conditions is even more uncertain. If the global mean surface temperature increases, then sea level is predicted to rise, primarily due to the thermal expansion of the oceans and to a melting of some land-ice. The current predicted range of sea level increase lies between about 10 and 30 cm, at the time of an equivalent doubling of carbon dioxide (sometime during the middle of the next century).

Ecological Systems:

Biological Productivity: Warming of soils will tend to increase nutrient availability to plants with potential for increased productivity. Further, increased temperature will affect respiration more than photosynthesis, possibly reducing carbon stored in terrestrial ecosystems resulting in a positive feedback on atmospheric carbon dioxide concentrations. Higher atmospheric carbon dioxide concentrations can increase photosynthesis with potential increases in net production, but the duration of "carbon dioxide fertilization effects" is unknown. However, while there is some knowledge of the responses of biological production processes to changes in parameters of the physical environment, how these integrate over the life cycle of even one species interacting in a complex of other species is unknown.

Ecosystem Composition: Species will respond differently to changes in temperature, precipitation and atmospheric carbon dioxide, either singly or in some combination. However, exactly what these responses will be is not known. Also unknown are the changes that will occur among species, including plant-animal and plant-microbe interactions.

Marine Ecosystems: The historical record leaves little doubt that global warming will have an impact on marine planktonic organisms. The structure and productivity of marine ecosystems are strongly influenced by ocean circulation and mixing, with such physical parameters tightly linked with climate. While there is considerable knowledge of specific processes and specific parts of the global oceans, the integration of this knowledge is incomplete and significant gaps in understanding exist.

Climate Change

Summary of Current Understanding and Recent Developments

Key Talking Points:

1. The Earth's climate is highly variable. The natural ranges of climate variability (e.g., temperature) are characteristically quite large compared to human-induced signals.

2. Human activities are increasing the atmospheric concentrations of greenhouse gases, but uncertainties about their sources and sinks limit the formulation of effective control strategies.

3. Computer-based models of the climate system are currently the best available tools to integrate information about changing climate conditions. While these models all predict the Earth's temperature will increase in response to an increase in the atmospheric concentrations of greenhouse gases, it must be remembered that there are numerous scientific uncertainties concerning the prediction of the magnitude and timing of climate change, especially at the regional scale. Perfecting these models so that they become true prediction tools is one of the key objectives of the US/GCRP.

4. Observational evidence suggests that the global mean surface temperatures have increased by between 0.3 and 0.6 degrees centigrade within the last one hundred years, but because of natural variability it is not possible to ascertain the cause of the observed increase. The observational record cannot be used to confirm or refute the presence of an "anthropogenic greenhouse" signal.

5. If a global warming were to be caused by increasing atmospheric concentrations of carbon dioxide and other long-lived gases (e.g., CFCs and nitrous oxide), then even with significant reductions in their emissions it would take a very long time, decades to centuries, to reverse the "anthropogenic" warming.

6. Predictions of changes in agriculture and natural ecosystems are not only limited by a lack of reliable regional climate change predictions, but also an inadequate understanding of how biological productivity and ecosystem composition will respond to environmental change.

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Elements of a Framework Treaty on Climate Change*

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by

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At the meeting in Nairobi last August of the Preparatory Committee for the 1992 United Nations Conference on Environment and Development, Maurice Strong, the Secretary-General of the Conference, identified a number of environmental concerns that could appropriately become the subject of multilateral conventions. Among them were climate change, biodiversity, sustainable development, forestry, and safety in biotechnology. Of them all, the most widely ramified and economically sensitive is climate change. It is also the only one on which the UN General Assembly has directed the Conference to prepare a framework treaty. Many of the issues that will have to be resolved in developing multilateral arrangements to deal with climate change are also basic to the other subjects of potential conventions. Much of what is said below applies equally to those other subjects.

Dimensions of the Task

The shaping of a framework treaty on climate change will not be easy. The negotiators will have to find ways of overcoming or getting around difficulties more dismaying than those surmounted by

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*The first version of this paper was prepared for a discussion involving the individuals named in the attached list. While the present version has greatly benefited from that discussion, no attempt has been made to determine the extent to which it reflects a consensus among their views. The paper has since then been strengthened by the helpful suggestions of Lance Antrim, Peter Hakim, Bernard Oxman, Benjamin Read, James Sebenius, and Peter Thatcher.

the negotiators of any previous multilateral agreement. The framers of the Law of the Sea Convention, the most complex and ambitious multilateral agreement thus far attempted, were able to draw on a highly developed body of customary international law. Their most innovative concepts adapted existing legal regimes to technological change (the exclusive economic zone and the continental margin provisions) and the prospect of a new industry (deep-seabed mining). Implementation of the LOS Convention will not entail massive economic shifts or sacrifices.

The framers of a multilateral treaty on climate change will not start out with the same advantages. Customary international law on the environment is scanty, and the existing multilateral agreements are narrow in scope. They protect humans, animals, fish, plants, insects, and other forms of life from the harms caused by toxic, radioactive, or disease-causing substances. These harms are widely recognized. Even in the case of the Montreal Protocol, the most future-oriented of the agreements thus far negotiated, it is generally accepted both that CFCs caused the ozone hole over the Antarctic and that the destruction of the ozone layer would have serious consequences. Moreover, none of the existing environmental agreements confers on an international institution the power to set binding standards, issue and enforce regulations, or prescribe sanctions. Few provide for dispute settlement.

By contrast, the damage that may eventually result from the accumulation of greenhouse gases cannot be seen or felt; the activities that are believed to be causing it are for the most part unrestricted. But the most striking distinction between climate

change and other environmental concerns is that the actuality of global warming is not only distant in time but fraught with uncertainty as to its probable extent and consequences.

The negotiating process is further complicated by the enormous and astonishing variety of the activities that generate greenhouse gases: wood fires, dairy farming, rice growing, power generation, air travel, grass burning, automobile travel, etc., etc., etc. Conducted on a vast scale, these activities are important in one way or another to every human being on earth. Large economic dislocations are bound to be set in motion by even the most conservative and non-coercive means of reducing the risk of climate change. It is inevitable, therefore, that industrial countries will resist constraints which impair their competitiveness and that developing countries will resist constraints which impair their growth.

By comparison with the limited harms addressed by existing environmental agreements, the devastation that could result from substantial global warming would far exceed the harm caused by any previous human action (except perhaps population growth). Moreover, the accumulation of greenhouse gases is irreversible. Notwithstanding uncertainty, this is a powerful reason for taking preventive action now. But if the long-term threat of climate change is enormous, so will be the short-term cost of averting it.

Although some of the actions demanded by a serious effort to curb the buildup of greenhouse gases will be painful, many, including energy conservation, will at the same time yield other benefits. Climate change aside, we should be taking steps to make

more efficient use of the power generated by coal-fired plants. The Gulf crisis has given new urgency to developing new energy sources and phasing out gas-guzzling automobiles. Other useful purposes will be served by checking deforestation and promoting reforestation, recycling more paper, cutting down on packaging material, lowering taxes on conservation land, and using more fuel-efficient stoves. Although largely instigated by health worries, a ban on CFCs will also eliminate a source of greenhouse gases. Meanwhile, the prevention of global warming needs to be seen as part of a broader atmospheric protection effort that includes reducing smog, curbing acid rain, and stopping other toxic emissions.

But the fact that there are many good reasons to protect the atmosphere is no guarantee that enough will be done. Nor is the necessity for a network of multilateral arrangements diminished because it is in every nation's -- or most nations' -- interest to combat climate change. The results of independent national action are bound to be highly uneven. From the standpoint of impact as well as of equity, there is no alternative to broad-based multilateral cooperation.

Approaches to a Treaty

As an original matter, the framework treaty on climate change that the UN General Assembly has directed the 1992 Conference to prepare could take one of three quite different forms. It could be covered by the charter for a global environmental protection agency with standard-setting, regulatory, and enforcement powers. It could be part of a comprehensive code of generalized obligations to do the right thing by the

environment. Or it could offer an array of procedural devices designed to stimulate action rather than prescribe it. Although the Law of the Sea Conference pioneered negotiating procedures that will serve the environment no less well than they served the oceans, it would not make sense to try to incorporate into a treaty on climate change detailed prescriptive language like that embodied in the Law of the Sea Convention. Besides, the Law of the Sea negotiations began 20 years ago, and the resulting Convention has not yet entered into force. If it is important to prevent climate change, it is important to begin now.

After a slow start, the process of evaluating alternative approaches to the framework treaty is beginning to get under way. The UN General Assembly has asked UNEP and WMO to lay the groundwork for the negotiations on a basis taking into account the work of the intergovernmental Panel on Climate Change. The Preparatory Committee for the 1992 Conference chaired by Ambassador Tommy T.B. Koh will stay in close touch with the UNEP-WMO process. The Conference itself, obviously, is not a suitable forum for a negotiation of this kind. It is essential to hope, therefore, that a consensus in favor of some version or variant of the three possible approaches will be hammered out before the delegates arrive in Rio de Janeiro.

The first approach would require delegating to a multilateral organization the power to override national environmental policies or practices. Significantly, not even the limited environmental agreements now in effect confer such authority. It is scarcely conceivable, therefore, that a consensus on the composition, decision-making, and regulatory powers of a

global EPA can emerge in Brazil. The effort to create such a consensus would in any case be bound to take a long time. An additional consideration, sufficient in itself to disqualify this approach, is its administrative unwieldiness. The attempt to impose uniform environmental prohibitions, constraints, controls, and standards on 150-odd sovereign states would inevitably provoke resistance and resentment in most of them. To overcome these reactions, the global EPA would have no alternative but to deploy a legion of inspectors and enforcers. This, rather than increasing compliance, could well have the opposite effect.

The second approach -- a comprehensive code of obligations -- would avoid these pitfalls. This approach also has some positive attributes. It would, for one thing, be a useful means of building a broad base of international acceptance of some important objectives. Within member states it would serve as a vehicle for mobilizing domestic support for urgently needed environmental reforms. As a self-contained instrument, however, a comprehensive code of obligations would have serious limitations. Not being declaratory of well-established customary law, it would take a long time to bring state practice into conformity with its precepts. Its necessarily vague and general language would be subject to highly variable interpretations. This same vagueness could also be used to rationalize resistance to higher standards. Standing by itself, a code of obligations lacks a viable means of making something happen.

The third approach comes from the opposite direction. Making things happen is its primary goal. For this purpose it can draw on an array of devices that includes data collection, technical

assistance, monitoring, reporting, and standard setting. It can also establish procedures for facilitating the adoption of supplementary agreements or protocols. Separately negotiated, these would deal with concrete problems whenever it became propitious to do so. Meanwhile, a permanent organization would operate the procedural machinery.

As previously noted, this approach aims at stimulating action rather than prescribing it. Its weakness is that, until the protocols begin to be adopted, it lacks any substantive content to which its machinery can be hooked up. But there is no reason why a code of obligations cannot be linked to procedures and no reason why action-oriented mechanisms cannot be used to promote the fulfillment of obligations. The obvious solution is to merge the second and third approaches. The qualities of each can thereby be made to offset the defects of the other.

Essential Elements of a Treaty

To improve the chances of building a consensus around a framework treaty combining substantive and procedural elements, it should be stressed from the outset of the negotiations that its adoption will constitute only the first stage in a continuing process. As time goes on, the gradual addition of supplementary protocols will supply the concreteness and specificity lacking in the general obligations. In due course either the basic treaty, the protocols, or both can be augmented by provisions for international dispute settlement, private rights of action in domestic courts, and even, perhaps, penalties for violations.

In addition, the framework treaty should contain a provision obligating member states to observe generally accepted

international environmental rules, regulations, and standards adopted through the competent international organization. Similar provisions are an important feature of the LOS Convention. Standards such as those established by International Maritime Organization conventions or contained in the regulations adopted pursuant to the London Dumping Convention are "generally accepted"; states that are party to the LOS Convention are thus obligated to observe these standards even though they are not parties to the conventions from which the standards derive.

To recapitulate, a framework treaty on climate change should contain three essential elements. The first is a statement of goals, principles, and general obligations. If the 1992 Conference succeeds in making this statement reasonably comprehensive and comprehensible, the effort to achieve substantive consensus can stop there: since the statement will, in any case, constitute only the first step in the process of elaborating progressively more concrete substantive agreements, its gaps, ambiguities, and inconsistencies will not be fatal; they can be dealt with later when and as the necessary consensus develops. The second is language establishing the procedures for negotiation and adoption of supplementary protocols. The third is specific provision for a series of auxiliary measures designed to encourage the voluntary adoption of national commitments, permit the monitoring of compliance with those commitments, and mobilize domestic and international public opinion.

To give effect to this framework, the treaty should also entrust to a permanent multilateral body such functions as data collection, laying the groundwork for supplementary protocols,

administering the auxiliary measures, providing technical assistance to member states, and monitoring national performance. It should also create a special fund for the support of these activities. If it were decided to make the body a specialized UN agency, its charter should provide for funding by financial assessment of member states. It would need, in any case, to have some kind of an executive council whose size, composition, and voting procedures would have to be thrashed out.

It is not obvious what kind of an organization would best fill the bill. Some of us think it should be a beefed-up UNEP. Others believe that an entity patterned on the GATT or the IMF would be more suitable. Assuming that the multilateral body has a clearly defined mandate and the powers and resources needed to carry it out, it may not make a crucial difference whether an old agency is given new duties or a new one is brought into existence. For purposes of the discussion to follow, the term "multilateral environmental agency" should be understood as embracing both.

Role of a Multilateral Environmental Agency

Several of the functions that a multilateral environmental agency (MEA) should be directed to perform have already been mentioned. Since the MEA will not have a regulatory role backed up by enforcement powers, it will have to make the most of a number of devices that do not depend on the coercive force of official sanctions. This need not mean, however, that the MEA is powerless. Recent experience has shown that non-coercive devices like the auxiliary measures touched on above can be effective in promoting the observance of international norms. This is already happening in the human rights arena, where non-governmental

organizations that investigate and publicize violations of the Universal Declaration of Human Rights help to mobilize international opprobrium against offending governments. The very process of implementing a framework treaty on climate change will create awareness that governments have no more right to mistreat their environments than their people.

The MEA should have a role in many if not most of the mechanisms called upon to carry out the purposes of the framework treaty. In roughly ascending order of intrusiveness, these mechanisms include the following:

- The definition of targets, which would be set voluntarily on a country-by-country basis.
- The adoption, also country-by-country, of strategies for reaching these targets.
- Periodic progress reports to the MEA.
- Monitoring of national performance by international observer teams recruited and trained by the MEA.
- Verification of nationally declared greenhouse gas emissions by remote sensing systems.
- Publication by the MEA of reports assessing national performance.
- Technical assistance to developing countries to enable them to deal with the problems thus identified.
- Promulgation by the MEA of recommended standards differentiated, inter alia, by measurable stages of economic development.

- Procedures for dispute resolution ranging from conciliation through mediation to binding arbitration.
- The opportunity to seek injunctive and monetary relief for noncompliance with generally accepted standards in the administrative and civil courts of member states.

The skillful use of these devices would create substantial incentives for member states to improve their environmental performance. Non-governmental organizations would be watching, exhorting, and pushing. Domestic awareness of the national effort would be heightened by the international attention it attracted. Media coverage would be correspondingly intensified. The attention thereby focused on the government's response would generate pressure to raise its level. It is arguable, indeed, that the self-reinforcing process thus set in motion could become a formidable substitute for official action -- more effective than regulation and far less expensive than its enforcement. If this happens, what has generally been called "soft law" will become progressively harder.

Meanwhile, the multilateral lending institutions still have room to increase their insistence on responsiveness to environmental concerns. It is also essential that they help to compensate developing countries for economic losses caused by their observance of environmental constraints and give them incentives to adopt policies conducive to sustainable growth. One important but inexpensive institutional change that could give major encouragement to sustainability would be the incorporation of

resource accounts in all national economic accounts. The developing countries will also require assistance in obtaining environmental technology and in building national capacities for environmental research and teaching. It is encouraging that the World Bank is prepared to commit substantial resources to the Global Environmental Facility now being developed.

Coordination of Research

There is a need, finally, for the best possible international coordination of research on the extent, causes, and consequences of climate change. The coordination process should ensure widespread participation by developing countries and embrace the allocation of roles among regions and organizations, the transition between research and operations, the involvement of industry, and the continuing development of environmental indicators.

There is a need as well for the application of science and technology to the development of better alternatives to climate-affecting practices and the design of more efficient regulatory techniques. The present level of coordination among the existing international environmental programs and organizations is not adequate to the purpose of systematically addressing these and other global environmental issues. In the case of climate change, the framework treaty should require the MEA to assemble and disseminate scientific information and to cooperate with the WMO in supporting activities designed to improve the collection and analysis of such information.

Conclusion

Although the atmosphere is the universal sustainer of life on earth, no such universality can be found in the diverse national interests affected by every proposal to protect this global common. To have a chance of wide acceptance, therefore, a framework treaty on climate change must be capable of adaptation to the varying situations of individual countries. This, indeed, is the rationale for most of the mechanisms enumerated above, starting with the setting of national targets.

Rather than wait for universal consensus, groups of countries with analogous interests and capabilities may wish to pursue agreements among themselves. The framework treaty should be able to accommodate such small-scale agreements. For example, a group of developed nations might agree among themselves both to undertake significant anti-greenhouse actions and to couple these initiatives with assistance to developing countries in acquiring the relevant technologies. Such an agreement, linked to the framework treaty, would help to encourage earlier and more positive action than would otherwise occur. In short, the framework treaty should be just that -- a framework.

To reemphasize a point made earlier, the negotiation of a framework treaty on climate change must from the outset be understood and accepted as the first step in a continuing process. Negotiations within and among many groups and on many levels will have to go forward long after the framework treaty itself has entered into force. Sustaining this process will require strong leadership, sound strategic judgment, and tactical skill. Never easy to come by, these qualities will be in increasing demand as

the world community comes to grips with the pervasive concerns that transcend the capacity of any single nation.

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