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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

OA/ID Number:	62047
Folder ID Number:	62047-001

Folder Title:
Environment - General [1989]

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

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01. Memorandum	To: President Bush From: Domestic Policy Council Re: Hazardous Waste Export (4 pp.)	3/3/89	(b)(1)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: General Science Files
WHORM Cat.:
File Location: Environment - General [1989]

Date Closed: 4/1/2010	**OA/ID Number:** 62047-001
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]
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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)]

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THE WHITE HOUSE

WASHINGTON

November 29, 1989

~~CONFIDENTIAL~~

Determined NOT to be
National Security Classified Marking
By MB (NLGB) on 4/1/10

Dear Dave:

This is a belated response to your letter of October 31, which arrived while I was in the Netherlands at a huge meeting on global warming.

There are, in fact, two positions that I think you might be interested in, one open at the moment, and one that will become open next September. The first is that of Director of the Office of Energy Research in the Department of Energy. As you know, Bob Hunter terminated his appointment at the request of Admiral Watkins abruptly a few weeks ago, and Jim Decker is again serving as Acting Director. This causes me some considerable difficulty, because Jim was all set to accept appointment as Assistant Director for Physical Science and Engineering in my office and now feels committed to holding down the fort until a replacement is selected by the Admiral. I know that Admiral Watkins has talked with Al Neuharth, who is currently director of the Sandia Laboratories, and with Harold Fortzen, who is currently with Battelle, but in both cases has received a negative response, so that he is still looking.

The second position is that of Director of the National Science Foundation which will become vacant next September when Erich Bloch completes his six years in the post. A major search committee activity will be undertaken, starting in the very near future. It will be chaired by Dr. Mary Good, of Allied Signal, who is currently chairman of the National Science Board.

If either of these positions are of interest to you, I would suggest that you immediately get a resume to Admiral James D. Watkins, Secretary of Energy, and to Dr. Mary Good, Chairman, National Science Board, as soon as possible, indicating that I suggested that you should do so.

Unhappily, in both of these cases, and indeed in my own, the situation does not promise to be as much fun as it was in

Jay Keyworth's time, when research budgets were increasing at a reasonably healthy rate. I suspect that the next few years will be difficult ones, with a number of very hard budget decisions being required each year -- decisions that will make the scientific community and the Congress and, in fact, everyone else, unhappy. This is really the first time, since the War, when I suspect that it will be the case that even very high-quality projects will not be able to move forward, if not immediately then eventually, because we simply have more high-quality people and projects than can be supported with any reasonable extrapolation of current budgets.

On the other hand, this is when leadership is required, and I think that you could have a very real impact if you were to find yourself in either of these positions.

The membership of the President's Council of Advisers on Science and Technology (PCAST) has now been fixed and has involved a remarkable amount of balancing and adjusting for geographical, professional and an amazing array of other attributes. Unfortunately, you were not included in the final list of initial appointees, although that certainly does not imply that with the expected turnover that you will not become a member of that group in the not too distant future.

I have now completed the senior staff at the Presidential appointment level in my own office. Jim Wyngaarden and Tom Ratchford were confirmed by the Senate at 1:00 a.m. on Saturday morning, November 18, and your colleague, Eugene Wong from Berkeley, will be confirmed as Associate Director for Physical Science and Engineering, and Dr. William Phillips, formerly executive vice president of both Mallincropt and DuPont, as well as chairman of the chemistry department at Washington University in St. Louis, will be confirmed as Associate Director for Industrial Technology, very soon after the Senate reconvenes early in the new year. I believe that this group has a remarkable degree of complementarity and that, together with me, will represent a collegial group that will be able to address the problems that boil up through the system to the Presidential level in reasonable fashion.

Please let me know what you decide to do about the DOE and NSF positions. Let me also emphasize that, in both cases, this is still to be considered as confidential and, in particular, in the NSF case, the search procedure has not yet been announced but I suspect will be early in the new year.

With warmest best wishes to both you and Virginia, and with the hope that the remainder of your stay in Berlin will be a pleasant and rewarding one,

Sincerely yours,

Allan

D. Allan Bromley
Assistant to the President
for
Science and Technology

Professor David A. Shirley
Free University of Berlin
Faculty of Physics
Institute for Atomic and Particle Physics
WE 1, Arnimallee 14, 1000 Berlin 33
Federal Republic of Germany

~~CONFIDENTIAL~~

FREIE UNIVERSITÄT BERLIN
Fachbereich Physik
Institut für Atom- und Festkörperphysik (WE 1)

FU | BERLIN

October 31, 1989

Freie Universität Berlin, Fachbereich Physik
WE 1, Arnimallee 14, 1000 Berlin 33
Tel.: (030) 838
(Tx 17308622 + Ttx 308622=fuphysk)

Dr. D. Allan Bromley
Assistant to the President
for Science and Technology
Room 358, Old Executive Office Building
Washington, D.C. 20500

PERSONAL

Dear Allan,

I'm writing for two reasons. First, to send greetings from Berlin, where we're comfortably ensconced doing science, seeing Europe at a more leisurely pace, and having the time of our lives!

The second reason is to let you know that I have become quite serious about seeking a more challenging position than the professorship which awaits me in Berkeley. The difference from earlier this year is that now I'm thinking of a permanent move to a position in science or university administration. I'm writing to you both as a friend and because I recall that it was Jay Keyworth who ordered Hermann to go and be the director of CEBAF! Thus I surmise that knowledge of openings will reach your Office. Please remember me if something suitable for this ex lab director comes along.

To minimize the trauma (or celebrations) in Berkeley, I'd like to keep this process confidential. Anything sent to my Berkeley address will be forwarded discreetly by my secretary. Alternatively, my home address here is

Garystrasse 65
1000 Berlin 33
W. Germany.

My home direct-dial telephone number is 011 49 30 8313523, and my e-mail address (bitnet only) is

st%"dashirley@vax1.physik.fu-berlin.dbp.de"

all of which is needed. Please share this information with anyone who has an appropriate job to offer, and I'll send a c.v. and references on request.

I have heard that you are doing a great many good things for the country in your new role: count me among your many fans! Thanks again for your responses this last summer.

Cordially,

Dave

David A. Shirley

Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
02. Memorandum	To: John Sununu From: Allan Bromley Re: EPA Regulations (1 pp.)	11/3/89	(b)(1)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: General Science Files
WHORM Cat.:
File Location: Environment - General [1989]

Date Closed: 4/1/2010	**OA/ID Number:** 62047-001
FOIA/SYS Case #: 2005-0336-F	**Appeal Case #:**
Re-review Case #:	**Appeal Disposition:**
P-2/P-5 Review Case #:	**Disposition Date:**
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Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
03. Memorandum	To: John Sununu From: Allan Bromley Re: Impact of Launches on Stratospheric Ozone (1 pp.)	11/29/89	(b)(1)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: General Science Files
WHORM Cat.:
File Location: Environment - General [1989]

Date Closed:	4/1/2010	**OA/ID Number:**	62047-001
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Withdrawal/Redaction Sheet
(George Bush Library)

Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
04. Memorandum	To: James Baker From: Allan Bromley Re: Frederick Bernthal (1 pp.)	11/15/89	(b)(6)	

Collection:

Record Group: Bush Presidential Records
Office: Science and Technology Policy, Office of (OSTP)
Series: Bromley, D. Allan, Files
Subseries: General Science Files
WHORM Cat.:
File Location: Environment - General [1989]

Date Closed:	4/1/2010	**OA/ID Number:**	62047-001
FOIA/SYS Case #:	2005-0336-F	**Appeal Case #:**	
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THE WHITE HOUSE

WASHINGTON

November 3, 1989

MEMORANDUM FOR JOHN H. SUNUNU

FROM: D. ALLAN BROMLEY Allan

SUBJECT: NEW, NOVEMBER 1, EPA REGULATIONS ON RADIONUCLIDE EMISSIONS

A great deal of controversy surrounds EPA's promulgation of their new standard on radionuclides where it concerns NRC-licensees. A 90-day stay for reconsideration of this category of emitters was requested but the justification given was focused mainly on the nuclear medicine facilities alone. The **main issue** should have been the dual regulating of all the NRC-licensed facilities by EPA as well as by the NRC.

Some would argue that the best way to handle the situation now, is to have a jointly signed letter go to the Congress requesting legislation to eliminate dual regulation for radionuclides. The sponsors of the letter would be NRC, DOE, NIH, and EPA. (EPA agrees to do this but they have a different text than the other agencies.) Since a similar tactic was used for mixed waste and could never get resolved by Congress, I don't believe this process has any chance of success -- no matter how many stays EPA requests from the Court. When the stays cease, EPA will then have to regulate unless the Court rules otherwise. UNLIKELY!

I believe there is a way to resolve this problem. It is a **regulatory**, not legislative, **solution**. My staff informs me that OMB's regulatory oversight group (OIRA) can require EPA to submit to OMB's OIRA the technical justification for such dual regulation of the NRC-licensees. A reason such as EPA gave in their new regulation (see attached) -- "EPA has decided to regulate this category to insure that the current levels of emissions are not increased." -- does not form the basis for the duplication and redundancy the dual monitoring would create. Assuming EPA cannot make an adequate justification, OIRA can then require the removal of that category -- NRC-licensees -- from these new radionuclide regulations.

Attachments

10 mrem/y ede, will protect public health with an ample margin of safety.

EPA has decided to regulate this category to insure that the current levels of emissions are not increased. The requirements of the rule assure that UFC facilities will keep emissions at or below the level of the standard, thereby insuring an ample margin of safety. The reporting provisions also provide the public with information on the emissions from the facility and provides them with assurance that the emissions will remain safe with an ample margin of safety, regardless of changes in the facility or the local population. Moreover, because each facility subject to this rule must demonstrate compliance with the 10 mrem/y ede emissions standard, it is likely that most, if not all, exposed individuals will receive a dose significantly less than 10 mrem/y ede. Therefore, EPA is promulgating a NESHAP mandating that radionuclide emissions from UFC facilities shall not cause any individual to receive a dose greater than 10 mrem/y ede.

4. Implementation

EPA has determined that the same level of regulation is appropriate for both UFC facilities and NRC-licensees. Therefore, EPA has removed the exemption for UFC facilities in the NRC-licensee NESHAP and will regulate them exactly the same as other licensees, including reporting and recordkeeping requirements.

EPA approves the use of the current version of NRC regulatory guidances for use in determining the emissions from

EPA's Radionuclide Emission Standard

SYNOPSIS:

Released 11/1/89 : sets a 10m rem/yr limit on nuclear licensees' radionuclide emissions.

A 90-day stay for reconsideration (with a 60-day comment period) was requsted for NRC licensees, ostensibly due to "recent" input from NIH and NRC regarding duplicative regulation and negative effects of the rule on medical treatment. However, the wording of the stay is unclear whether nuclear power plants are included in the reconsideration.

CONCERNS UNDER THE NEW RULE:

Dual regulation of nuclear power facilities would continue. Additionally, states may seize the opportunity to set more stringent limits.

This rule sets an emissions limit despite EPA having determined that the risks from our plants "are acceptable" (p. 73 of new rule). However, other source categories with acceptable risks were not regulated under the Benzene policy, which EPA cites as its fundmental policy.

In addition, this ruling appears to be counter to the intent of the Clean Air Act which requires regulation to be based on control of risk.

The reason given by EPA for setting a limit for nuclear plants is "to insure that the current levels of emissions are not increased" (p. 77 of new rule). No justification is provided to substantiate the basis for that speculation. ALARA applies to nuclear plants under NRC rules.

EPA recently has been expressing concern to avoid dual regulation, but their actions indicate they insist on EPA regulation of all emissions despite creation of a dual regulation situation. EPA appears unwilling to agree with NRC, DOE, and HHS in preparing a joint letter to Congress on the inadvisability of dual regulation and asking Congress to resolve.

NRC, DOE, and HHS are clearly in support of eliminating dual regulation.

RESOLUTION:

EPA should decide that the existing EPA and NRC regulations for radionuclide emissions from commercial nuclear power plants and fuel fabrication facilities are properly controlling the public health risks. Additional regulation for these facilities should not be imposed because it will expend regulatory and industry resources and will not result in human health benefit.

This approach is proper because 1) it complies with the Clean Air Act, 2) complies with the court's ruling in the Vinyl Chloride Case, and 3) the current EPA and NRC regulations very effectively control the risks for nuclear power plants.

United States
Environmental Protection
Agency

Office of
Public Affairs (A-107)
Washington DC 20460

EPA Environmental News

FOR RELEASE: WEDNESDAY, NOVEMBER 1, 1989

EPA SETS NEW RULES FOR RADIOACTIVITY FROM INDUSTRIAL SOURCES

Dave Ryan (202) 382-2981

Final rules controlling radon and other radionuclide emissions from industrial sources such as nuclear weapons plants, nuclear power plants and uranium mines were announced today by the U.S. Environmental Protection Agency.

A radionuclide is a type of atom which spontaneously disintegrates into a different atom. People are exposed every day to radionuclides from a variety of natural and manmade sources. Natural sources of radiation include cosmic rays, radon gas and other terrestrial sources. Manmade sources include medical and dental X-rays, fallout from above-ground nuclear weapons testing and industrial facilities. Today's air pollution rules apply only to airborne releases from industrial facilities.

Industry uses hundreds of different radionuclides in solid, liquid and gaseous forms. Industrial radionuclide emissions occur either as a result of an inability to contain the radioactive materials or as an unintended consequence of other activity, such as radionuclide emissions (usually radon) from mining or milling. An example of this second category is phosphogypsum piles. These piles emit radon because radium (from which radon gas is produced by radioactive decay) is found naturally in the same soils that are the source of phosphate rock.

"Today's rules will protect public health from the risks of industrial radioactivity," said William G. Rosenberg, EPA Assistant Administrator for Air and Radiation. "As a result of these regulations, over 90 percent of all Americans in the vicinity of these industries will have less than one chance in a million of contracting fatal cancer from radionuclides."

Numerous studies have demonstrated that radiation is a carcinogen. Although hereditary and developmental effects were considered in this rulemaking, cancer generally occurs more often and its effects are more severe. EPA believes that the level of protection mandated by this rule against cancer is sufficiently stringent to protect against hereditary and developmental effects.

(more)

Rosenberg expressed frustration with the hurdles EPA must overcome in protecting the public from radioactive and other hazardous air pollutant risks:

"Radionuclides provide a good example of the difficulties EPA faces in trying to reduce hazardous air emissions under the existing Clean Air Act. EPA officially designated radionuclides as hazardous air pollutants in 1979 and proposed standards for them in 1983. Yet lengthy litigation and related battles on health risk assessment issues has meant it's taken 10 years to get final rules on the books.

"Since the Clean Air Act was passed in 1970, EPA, despite its best efforts, has been able to regulate only eight hazardous air pollutants. Reducing hazardous emissions under the current legislative structure and various court mandates is a lengthy, complex and cumbersome process, due in part to unresolved debate on acceptable levels of risk. The air toxics portion of President Bush's clean air proposal is a much better way to go. The President's bill gives Americans significant protection from toxic emissions right up front through the use of maximum achievable pollution-control technology. I urge speedy Congressional action to pass the President's bill to give Americans the health and environmental protection they want."

Today's rule covers an estimated 6300 facilities in the following source categories:

Source Category	Approximate number of active facilities
1. Nuclear Regulatory Commission and non-Department of Energy federal facilities	6000
2. Nuclear power reactors & their support facilities	135
3. Disposal of uranium-mill tailings piles	46
4. Department of Energy facilities	45
5. Phosphogypsum piles	40
6. Licensed uranium-mill-tailings piles	4
7. Elemental phosphorus plants	5

(more)

8. Department of Energy radon sources — 5

9. Underground uranium mines — 15

These final regulations are issued under authority of the National Emissions Standards for Hazardous Air Pollutants provision of the Clean Air Act (Section 112). Under this section, EPA is required to establish emission standards for hazardous air pollutants at a level which provides an ample margin of safety to protect public health.

Radionuclides are the second set of hazardous air pollutant regulations issued (after those set for benzene in August) since the landmark 1987 ruling by the Federal Appeals Court of Washington, D.C., on vinyl chloride. In that decision, the court mandated a two-step process for regulating hazardous air pollutants under Section 112.

In the first step, EPA must establish an "acceptable" level of risk based solely on health considerations. In the second step, the Agency must then set enforceable standards that provide an "ample margin of safety" to the public. In determining the ample margin of safety, EPA may take pollution-control costs and technological feasibility into consideration. The final enforceable standard developed in the second step can be tougher, but not weaker than, the "acceptable" level of risk developed in the first step.

In protecting public health with an ample margin of safety under this rule, EPA is seeking to protect the greatest number of people possible, so that their lifetime risk of developing cancer from these sources is less than one in a million. EPA is limiting the estimated risk of a person living in close proximity to a radionuclide emission source to no greater than approximately one in 10,000, assuming that person was exposed to the maximum pollutant concentrations for 70 years.

The NRC-licensees source category covers a large variety of different types of facilities licensed to process radioactive material, including hospitals, radiopharmaceutical manufacturers, laboratories and research reactors. EPA has granted a reconsideration on this source category due to some recent information supplied by NRC and the National Institute of Health, indicating that this rule may adversely affect the ability of some medical facilities to use certain types of radiotherapy. In addition, the reconsideration will examine ways to reduce the regulatory burden caused by the dual regulation of these facilities by EPA and NRC. EPA is also issuing a 3 month stay of this part of the rule as provided in the Clean Air Act.

(more)

Besides radionuclides, EPA has proposed or set final uniform, national hazardous air pollutant emission standards for asbestos, beryllium, mercury, vinyl chloride, arsenic, benzene and coke oven emissions.

The final rules will appear soon in the Federal Register.

For further information, contact Terrence McLaughlin, Environmental Standards Branch, Criteria and Standards Division (ANR-460), Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460; or call 202-475-9610.

###

individual risk to any individual is approximately 1.5×10^{-4}. In establishing the policy for setting NESHAPs in the context of benzene, the Agency determined that emissions resulting in a lifetime MIR no greater than approximately 1×10^{-4} are presumptively acceptable. In light of the numerous uncertainties in both establishing the parameters for the risk assessment and in modelling actual emissions and exposure, as well as the recognition that in achieving compliance, sources will generally control so as to ensure a buffer exists below the actual level of a standard, EPA judges that the MIR of 1.5×10^{-4} is essentially equivalent to the presumptively safe level of approximately 1×10^{-4}. EPA then considered the other risk factors in order to make an overall decision on acceptability. The estimated annual incidence is 0.1 fatal cancer per year, and approximately 99% of that risk is borne by people whose risk is less than 1×10^{-6}. Only 60 individuals incur a risk greater than 1×10^{-4}, and the incidence in the level greater than 1×10^{-4} is only 0.00093.

After examining these factors, the Administrator has determined that the baseline risks from UFC facilities are acceptable.

Uranium Fuel Cycle

H-79-11
XIII-

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 61

National Emission Standards for Hazardous Air Pollutants; Regulation of Radionuclides

AGENCY: Environmental Protection Agency [EPA]

ACTION: Final Rule and Notice of Reconsideration

SUMMARY: This notice announces the Administrator's final decisions on National Emission Standards for Hazardous Air Pollutants (NESHAPs) under Section 112 of the Clean Air Act for emissions of radionuclides from the following source categories: DOE Facilities, Licensees of the Nuclear Regulatory Commission and Non-DOE Federal Facilities, Uranium Fuel Cycle Facilities, Elemental Phosphorus Plants, Coal-Fired Boilers, High-level Nuclear Waste Disposal Facilities, Phosphogypsum Stacks, Underground and Surface Uranium Mines, and the operation and disposal of Uranium Mill Tailings Piles. The notice also responds to the major public comments on the March 7, 1989 proposed decisions for these categories [54 FR 9612]. EPA is conducting this rulemaking pursuant to a voluntary remand and a schedule issued by the U.S. Court of Appeals for the D.C. Circuit which requires final action by October 31, 1989. [In addition EPA is granting a reconsideration of the standards of 40 CFR Part 61 Subpart I, with respect to the issues of 1 duplicative regulation and possible effects on 2 medical treatment.]

EFFECTIVE DATE: (Date of publication in FEDERAL REGISTER). Under Section 307(b)(1) of the CAA, judicial review of decisions under Section 112 is available only by filing a petition for methodologies and quality assurance programs described in paragraph 61.107(b) or may use the following:

Section I

(1) Nuclear power reactors may determine their radionuclide emissions in conformance with the Effluent Technical Specifications contained in their Operating License issued by the Nuclear Regulatory Commission. In addition, they may conduct a quality assurance program as described in the Nuclear Regulatory Commission's Regulatory Guide 4.15 dated February 1979.

(2) Fuel processing and fabrication plants and uranium hexafloride plants may determine their emissions in conformance with the Nuclear Regulatory Commission's Regulatory Guide 4.16 dated December 1985. In addition, they may conduct a quality assurance program as described in the Nuclear Regulatory Commission's Regulatory Guide 4.15 dated February 1979.

(3) Uranium mills may determine their emission in conformance with the Nuclear Regulatory Commission's Regulatory Guide 4.14 dated April 1980. In addition, they may conduct a quality assurance program as described in the Nuclear Regulatory Commission's Regulatory Guide 4.15 dated February 1979.

Section 61.108 Exemption from the Reporting and Testing Requirements of 40 CFR 61.10.

All facilities designated under this subpart are exempt from the reporting requirements of 40 CFR 61.10.

Subpart K - National Emission Standards for Radionuclide

EPA has decided that the system discussed for DOE facilities also be used for this source category except that the sources will not use CAP-88 to calculate the doses. Instead they will use the screening models (COMPLY code) described in the BID.

5. Reconsideration of NRC Licensee Category

Late in the rulemaking, issues related to the application of the standard in Subpart I to NRC licensees were presented to EPA which raised serious concerns about possible effects of duplicative, and perhaps conflicting, standards on NRC-licensees, including, for example, the use of radioisotope therapies by the National Institute of Health (NIH) and other medical facilities. The concerns arise from the fact that these licensees would be regulated by both a Clean Air Act standard under Subpart I and an existing NRC standard under 10 CFR Part 20. While the level of health protection achieved under the NRC standard is generally comparable to that required by EPA's rule, the two standards are very different in form, and the means of demonstrating compliance with each standard impose significantly different regulatory requirements. The basic issue is whether these different regulatory requirements will discourage the use of radioisotopes in medical and experimental therapies. In addition, NRC has raised the issue of whether regulation of its licensees under a Clean Air Act standard provides any additional public health benefits.

EPA has expressed similar concerns in past proceedings on

THE WHITE HOUSE

WASHINGTON

October 13, 1989

MEMORANDUM FOR JOHN H. SUNUNU

FROM: D. ALLAN BROMLEY DAB

SUBJECT: Global Change Activities

In case you had not seen it previously, I enclose herewith a copy of a recent item published in Nature concerning the factor of 2 reduction in the temperature change predicted in the U.K. global change models following a first order introduction of cloud phenomena. In my view, this simply highlights the uncertainties in our present predictive capabilities in this area and the difficulties and dangers involved in basing major greenhouse amelioratory programs on current predictions and understanding unless there are other major independent reasons why the individual programs make sense at the present time.

I have been concerned by recent rumors to the effect that EPA was moving toward support of CO_2 reduction programs of a substantial nature. I have been unable to make contact directly with Bill Reilly to check this out because we have recently had essentially orthogonal calendars. Recently I had a visit from Mindir Baldur Wagner, the Director of Domestic Programs in the FRG's Chancellor's Office, who is a strong supporter of such programs. He mentioned to me in passing that he was surprised by my position that the currently available science did not support such programs at the present time when EPA, with whom he had visited just previously, had indicated strong support for programs directed toward major CO_2 emission reduction prior to 2000. He wanted to know which was the official U.S. position, and I believe that it is important for us to settle this matter internally so that we can present a united, coherent posture in our discussions with foreign groups and leaders.

Attachment

CLIMATE CHANGE

Wetter clouds dampen global greenhouse warming

Tony Slingo

VARIATIONS in cloudiness can significantly affect the Earth's radiation budget — the absorbed solar energy and the thermal energy radiated back to space[1]. This conclusion is supported by various modelling studies of the 'greenhouse' effects of increased CO_2 concentrations[2-4]. In these studies, the CO_2 forcing induces changes in the cloud coverage and liquid-water content, which alter the radiation budget further and thus modify the original perturbation. On page 132 of this issue[5], Mitchell *et al.* add a new twist to the story, showing how changes in the relative amounts of ice-crystal and water-drop clouds substantially reduce the sensitivity of their model to changes in concentration of CO_2. Indeed, it is becoming apparent that uncertainties in the treatment of clouds severely undermine model prediction of climate.

Mitchell *et al.* used various versions of the UK Meteorological Office atmospheric general circulation model[6] coupled to a 50-m ocean mixed layer[7]. Replacing the standard cloud prediction scheme based on relative humidity by a more sophisticated prescription including liquid water and ice virtually halves the average equilibrium surface warming due to doubled CO_2 — from 5.2 K to 2.7 K. They argue that this spectacular sensitivity to details of the cloud scheme is caused by the replacement of ice clouds by water clouds near the freezing level. In the new cloud scheme, the fall-speed assumed for water drops is much smaller than that for ice crystals, so that liquid-water clouds can dissipate more slowly than ice clouds. According to Mitchell *et al.*, this leads to the predicted relative increase in water clouds near the freezing level, which consequently reduces the amount of solar energy absorbed in the system (more is reflected back into space) and hence gives a smaller warming. When, in addition, cloud radiative properties are allowed to depend on the liquid-water content of clouds, the surface warming drops still further, to only 1.9 K.

The strong dependence of the magnitude of cloud feedback in this work on the details of the model parallels results presented recently[8] by a large *ad hoc* group (including Mitchell and myself) led by Robert Cess of the State University of New York. We compared 14 general circulation models and found a three-fold variation in global climate sensitivity, caused largely by differences in the cloud feedbacks. The models disagreed not only as to the magnitude but also the sign of the net cloud feedback. For this reason, it is clear that uncertainty in how to formulate clouds represents a formidable obstacle to reliable climate prediction.

This underlines the continuing need for physical parameterizations to be compared with results from field studies. This is particularly important now that models are becoming increasingly complex. Mitchell *et al.* argue that the assumptions in their model are 'at least qualitatively realistic', but if climate change simulations are to be believable, then all parts of a model must be validated quantitatively, and important processes that are ignored must be identified. Of particular relevance to the cloud problem is the FIRE programme (first regional experiment of the international satellite cloud climatology project), both in its stratocumulus[9] and cirrus[10] field phases. Several papers are in preparation that highlight the complexity of the mesoscale dynamical structure of cirrus, so that the fall-speed of ice crystals is only part of the story. It is also interesting that two cases of highly supercooled liquid-water altostratus clouds at temperatures around −30 °C were observed (A.J. Heymsfield *et al.*, personal communication), which suggests that the transition from water to ice clouds is more subtle than Mitchell *et al.* assumed for their model.

The substantial sensitivity of climate models to the details of their formulation, and the fact that 14 models give 14 different answers for the cloud feedback, show that we are far from the goal of accurate predictions of future climate change. Sensitivity studies such as that reported by Mitchell *et al.* and comparisons between models as done by Cess *et al.* are now the bread and butter of climate modelling. But at the present rate of progress, it will be several years before reliable predictions of global and regional climate change are available from the models. That underlines the need for comprehensive monitoring that is capable of unravelling the climate change signal from the noise and of providing enough data on the state of the atmosphere, the Earth's radiation budget and clouds for the feedbacks to be determined by observation. Such an analysis may well yield the fifteenth answer but at least it will have come from the real world and will permit a much needed test of the models. □

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1. Ramanathan, V. *et al.* *Science* **243**, 57–63 (1989).
2. Schlesinger, M.E. & Mitchell, J.F.B. *Rev. Geophys.* **25** 760–798 (1987).
3. Schlesinger, M.E. *Nature* **335**, 303–304 (1988).
4. Roeckner, E. *Nature* **335**, 304 (1988).
5. Mitchell, J.F.B., Senior, C.A. & Ingram, W.J. *Nature* **341**, 132–134 (1989).
6. Slingo, A., Wilderspin, R.C. & Smith, R.N.B. *J. geophys Res.* **94**, 2281–2301 (1989).
7. Wilson, C.A. & Mitchell, J.F.B. *J. geophys. Res.* **92**, 13315–13343 (1987).
8. Cess, R.D. *et al.* *Science* **245**, 513–516 (1989).
9. Albrecht, B.A., Randall, D.A. & Nicholls, S. *Bull. Am. met. Soc.* **69**, 618–626 (1988).
10. Starr, D.O'C. *Bull. Am. met. Soc.* **68**, 119–124 (1987).

ECOLOGY

Just proportions in food webs

Joel E. Cohen

IN FOOD webs of natural communities with varying numbers of species, the number of green plants and other species that consume no prey in the web (basal species) is nearly proportional, on average, to the number of species that have both predators and prey in the web (intermediate species), according to studies reported over the past dozen years[1-4]. Empirical rules[5,6] of that type describe structural or anatomical properties of food webs. An important question in community ecology is whether parallel regularities exist in the way in which food webs function[7]. On page 142 of this issue[8], McNaughton *et al.* report remarkable regularities in measures of food web function. Their findings indicate the existence of a physiology of food webs that generalizes across natural communities. Their report opens up the distant, but highly attractive, prospect of linking the previously known structural regularities with new functional patterns.

McNaughton *et al.* show that the biomass, consumption and net secondary productivity (NSP) of herbivores are all related to the net above-ground primary productivity (NAP) of a natural habitat by simple power laws. Particularly striking is that the exponent of the power law that relates NSP to NAP is not significantly different from 1: to a first approximation, NSP and NAP are directly proportional. In effect, the energy converted into herbivores per square metre of surface area per year is, on average, about one-thousandth of the energy that is converted into plants per square metre of surface area per year. The ecological energy pyramid has a much larger base than second storey.

This proportionality would be a triviality if secondary productivity were passively controlled and limited by primary productivity. But this trickle-down view of

TABLE 2 Newtonian error and signal strength

Distance r (m)	Maximum 1-μm shape error: Displacement f^2S ($m\,s^{-2}$)	Strain f^2h (s^{-2})	Fifth force: Displacement $f^2S\lambda^2/\alpha$ ($m^3\,s^{-2}$)	Strain $f^2h\lambda^2/\alpha$ ($m^2\,s^{-2}$)
2	4×10^{-18}	2×10^{-17}	1.1×10^{-13}	3×10^{-13}
4	1.3×10^{-19}	3×10^{-19}	1.4×10^{-14}	2×10^{-14}
8	4×10^{-21}	5×10^{-21}	1.8×10^{-15}	1.3×10^{-15}

The results detailed here show that it may be feasible to use the asymmetric monopole to test the fifth-force hypothesis, although the experiment is obviously not easy, and practical problems remain to be examined in detail. For example, there are small elastic distortions in a rotating body as a result of centrifugal forces. The shape defined by Table 1 is the shape that must be achieved at the final rotation speed. A numerical calculation would give the correct initial shape for a given material. Advantages of the experiment are that the experiment is a null one and one can adjust the shape to find the null, and that only octupole-patterned deformations give rise to error signals as large as in Table 2. Also, the parameters I have chosen (size, distance, tolerance and material) are nominal. There is also the possibility that a refinement of this idea, or an incorporation of the mathematical idea into other experimental techniques (such as torsion balances) may prove effective. I note that the experiment would not depend on any variation of the fifth force with chemical composition, as do many of the recent experiments. □

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1. Sinsky, J. A. *Phys. Rev.* **167**, 1145–1151 (1968).
2. Hyrakawa, K. & Kuroda, K. *Phys. Rev.* D**32**, 342–346 (1985).
3. Stubbs, C. W. *Nature* **338**, 301–302 (1989).
4. Stacey, F. D. *et al. Rev. Mod. Phys.* **59**, 157–174 (1987).
5. Duff, G. F. D. & Naylor, D. *Differential Equations of Applied Mathematics* 356 (Wiley, New York, 1966).
6. Ward, H. *et al. Proc. Int. Symp. Expl Gravitational Phys.* (eds Michelson, P. F., Hu, E.-L. and Pizzella, G.) 322–327 (World Scientific, Singapore, 1988).
7. Del Fabbro, R. *et al. Phys. Lett.* A**124**, 253–257 (1987).
8. Del Fabbro, R. *et al. Phys. Lett.* A**132**, 237–240 (1987).
9. Thorne, K. S. in *300 Years of Gravitation* (eds Hawking, S. W. & Israel, W.), 330–458 (Cambridge University Press, 1987).

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CO_2 and climate: a missing feedback?

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THE potential of changes in cloud properties to modulate climate perturbations is well known[1,2]. Changes in cloud amount and cloud height[3], cloud radiative properties[4–6] and cloud condensation nuclei[7] (CCN) have all been recognized as possible sources of climate feedbacks. Here we report results of simulations that indicate that the changes of state of cloud water may provide a substantial negative feedback on climate. The feedback is concentrated in mid-latitudes and affects both the magnitude and distribution of the climate change expected from increases in 'greenhouse' gases. Improved measurements and parameterizations of cloud processes are needed to quantify this process.

The model is an 11-level atmospheric general-circulation model on a 5°×7.5° (latitude×longitude) horizontal grid coupled to a 50-m mixed-layer ocean with a prescribed seasonally and geographically varying oceanic heat convergence to represent heat advection by ocean currents[8]. In the standard model[8] cloud cover is a function of relative humidity. A second version of the model was constructed with an explicit cloud-water variable for all but deep convective cloud[9]. A balance is maintained between cloud water content and water vapour, which is altered by dynamical, convective and boundary-layer processes. Cloud water content is depleted by precipitation at a rate dependent on the phase of the cloud water, which is a function of the local temperature of the layer. For water cloud the rate of conversion to precipitation increases as a function of the in-cloud water content and is marginally enhanced in the presence of precipitation from higher layers. The transition from water cloud to ice cloud occurs between −15 °C and 0 °C as a smoothly varying function of temperature. Ice-cloud particles are assumed to start falling as soon as they form, with a fixed fall speed of $1\ m\,s^{-1}$. The rate of precipitation of ice is, on average, an order of magnitude greater than that of water even in the presence of precipitation from the layer above. Cloud radiative properties were prescribed. Note that although the revised cloud scheme is more detailed, it is not necessarily more accurate than the less sophisticated scheme. Our work highlights how different parameterization schemes can affect the sensitivity of the climate to CO_2.

Two simulations, with CO_2 concentrations of 320 and 640 p.p.m., were performed for each version of the model. The results shown here are averaged over five years after the simulations reached equilibrium. On replacing the relative-humidity cloud scheme[8] (henceforth referred to as RH) with the model based on cloud water content[9] (CW), the global annual average surface warming is reduced from 5.2 K to 2.7 K. The largest fractional reduction in the warming occurs in higher latitudes (Fig. 1*a*) where the large decreases in total cloud cover with RH have been replaced by much smaller reductions or slight increases (Fig. 1*b*).

With RH, reductions in cloud cover are found throughout the depth of the mid-latitude troposphere (Fig. 2*a*), as in earlier studies[3]. With CW, the main differences in response occur near the freezing level (Fig. 2*b*) where, in the warmer doubled-CO_2

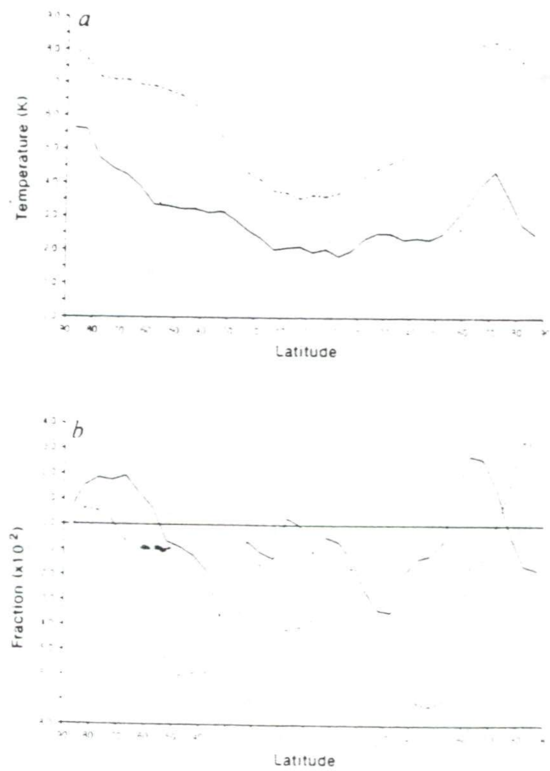

FIG. 1 Zone-averaged equilibrium changes in *a*, surface temperature and *b*, fractional cloud cover on doubling CO_2 (five-year means). Solid line, simulation with CW. Dashed line, simulation with RH.

simulation, ice cloud which is depleted rapidly by precipitation is replaced by water cloud which is depleted more slowly, so that cloud cover increases. This can be seen more clearly in the height-latitude distribution of the changes in cloud liquid water and cloud ice (Fig. 3). Also shown are the mean 0 °C and −15 °C isotherms in the control simulation. Because of the increases in cloud, the enhanced absorption of solar radiation in mid-latitudes found with RH is greatly reduced when using CW (Fig. 4).

One can define a climate sensitivity parameter λ $(=\Delta Q/\Delta T)$ where ΔQ is the change in radiative heating at the tropopause on doubling CO_2 and ΔT is the equilibrium change in surface temperature. Assuming[10] $\Delta Q = 4\ \mathrm{W\,m^{-2}}$, λ is increased from 0.77 to 1.48 $\mathrm{W\,m^{-2}\,K^{-1}}$ on replacing RH by CW. Thus changes in the phase of cloud water provide a strong negative feedback on climate, cancelling almost all the previous strong positive feedback from cloud in RH[11]. Although our model does not allow for this process in deep convective clouds, these have a small areal coverage and a relatively high liquid-water content, however, suggesting that any radiative feedback from this type of cloud would be small.

The lower-cloud increases in the simulations arise from the assumption that under similar conditions ice is removed more efficiently from cloud than water. In real water clouds, relatively few droplets become large enough to fall out, as the available condensed water is spread over many cloud condensation nuclei (CCN)[12]. Very few CCN act as ice nuclei[13], so in ice clouds the cloud water is spread over fewer, larger particles, all of which have appreciable fall speeds[14]. The microphysics of mixed-phase clouds are complex and not fully understood. Although our model does not explicitly represent them it effectively includes their most important aspect, the continual rapid conversion of water to ice[15]. A more complex representation would certainly change the pattern in Fig. 2 locally, but the vertically integrated response would probably depend primarily on the overall change from pure ice cloud to pure water cloud. Thus our assumptions concerning the relative fall-out of ice and water are at least qualitatively realistic.

As $1\ \mathrm{m\,s^{-1}}$ may be a large value for ice fall speed, we have rerun experiment CW using a parameterization of fall speed in terms of ice-water content based on observations[14] (experiment CWH). For typical simulated ice-water contents, this gives fall speeds of $0.2\ \mathrm{m\,s^{-1}}$ for high ice cloud and $0.7\ \mathrm{m\,s^{-1}}$ for ice cloud near the freezing level. Cloud changes (Fig. 2*c*) are qualitatively similar to Fig. 2*b* and the global warming is 3.2 K, only slightly larger than in CW. The similarity between CW and CWH is to be expected, given that the depletion rate of ice relative to water is large near the freezing level in both experiments.

It has recently been suggested that changes in cloud radiative properties may contribute an important feedback to climate[4,5,16]. In a warmer climate, greater cloud water content would increase cloud albedos (a negative feedback) and emittances (a positive feedback). A further experiment was carried out using the revised version of the model with an additional modification to

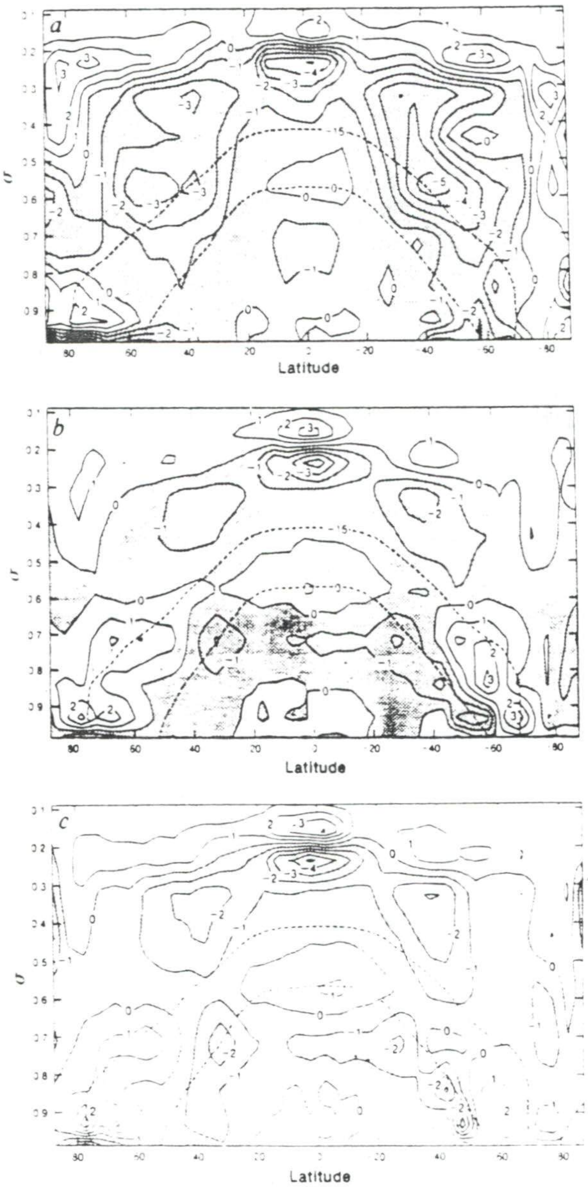

FIG. 2 Height-latitude cross-section of equilibrium changes in cloud amount on doubling CO_2. The height coordinate is σ (pressure/surface pressure). Areas of reduction are stippled and the contours are every 1%. The dashed lines are the 0 and −15 °C contours from the control simulation. *a*, Simulation with RH. *b*, Simulation with CW. *c*, Simulation with CWH.

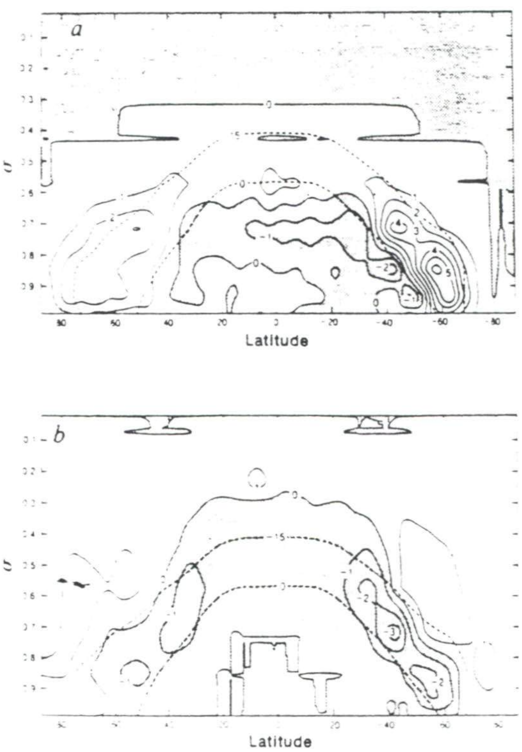

FIG. 3 Height-latitude cross-section of equilibrium changes in cloud water in CW on doubling CO_2. The height coordinate is σ. Areas of reduction are stippled. The dashed lines are the 0 and −15 °C contours from the control simulation. *a*, Liquid-water content only. Contours every $4\times10^{-6}\ \mathrm{kg\,kg^{-1}}$. *b*, Ice-water content only. Contours every $4\times10^{-7}\ \mathrm{kg\,kg^{-1}}$.

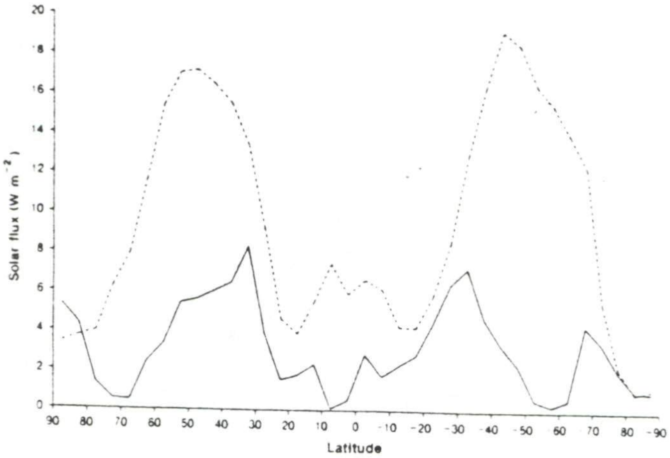

FIG. 4 Zone-averaged equilibrium change in net solar flux at the top of the atmosphere on doubling CO_2 (five-year mean). Solid line, simulation with CW. Dashed line, simulation with RH.

allow the cloud radiative properties to depend on the cloud water content (scheme CWRP). (Given the similarity between CW and CWH, this experiment was carried out with the CW formulation only.) Analytical fits of the short-wave albedo and transmittance as functions of cloud-water path and solar zenith angle were made to a published scheme[17] based on observations and theoretical considerations. The long-wave flux emittance was given by $(1-\exp(-\kappa q))$ where q is the condensed-water path and $\kappa = 0.13\ m^2\ g^{-1}$ for water clouds and $0.065\ m^2\ g^{-1}$ for ice clouds[18].

On doubling the CO_2 concentrations the global annual average equilibrium surface temperature increased by 1.9 K with CWRP compared to 2.7 K with prescribed cloud radiative properties (CW), indicating a further increase in λ to $2.1\ W\ m^{-2}\ K^{-1}$. This negative feedback from changes in cloud radiative properties lies between the very strong negative feedback suggested by one-dimensional calculations[16,19] and the positive feedback found in a previous study with a low-resolution general-circulation model (GCM)[4-6]. We note that all existing numerical studies assume that the number of CCN remains constant under climate change. Changes in CCN are a further possible source of feedback[7,20].

The sensitivity of the climate to doubling the CO_2 concentrations that we have found is substantially smaller than the 4–5 K found in other recent studies[10,21]. A significant part of this reduction in sensitivity is due to the different cloud scheme. If correct this will have two important consequences. First, the equilibrium warming expected from the estimated $2\ W\ m^{-2}$ increase in radiative heating at the tropopause since 1860 (ref. 9) will be smaller. Second, the proportion of the equilibrium reached will be greater, because the thermal response time of the climate system is reduced if climate sensitivity is reduced[22]. Based on calculations using a simple one-dimensional model of the ocean, the expected warming to date, using the climate sensitivity found when employing CW, is 0.6 K. This is close to the observed warming since the beginning of the century (0.5 K; ref. 23). The record of observations shows considerable variability on interannual and interdecadal timescales, however, including a period of cooling during the 1950s and 1960s, so that it is not possible to attribute the 0.5 K rise unambiguously to the effect of increases in trace gases. □

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1. Manabe, S. & Wetherald, R. T. *J. atmos. Sci.* **24**, 241–259 (1967).
2. Schneider, S. H. *J. atmos. Sci.* **29**, 1413–1422 (1972).
3. Wetherald, R. T. & Manabe, S. *J. atmos. Sci.* **45**, 1397–1415 (1988).
4. Roeckner, E. *et al. Nature* **329**, 138–140 (1987).
5. Roeckner, E. *Nature* **335**, 304 (1988).
6. Schlesinger, M. E. *Nature* **335**, 303–304 (1988).
7. Charlson, R. J. *et al. Nature* **334**, 418–420 (1988).
8. Mitchell, J. F. B. & Warrilow, D. A. *Nature* **330**, 238–240 (1987).
9. Smith, R. N. B. *Q. Jl R. met. Soc.* (in the press).
10. Dickinson, R. E. & Cicerone, R. J. *Nature* **319**, 109–115 (1985).
11. Wilson, C. A. & Mitchell, J. F. B. *J. geophys. Res.* **92**, 13,315–13,343 (1987).
12. Pruppacher, H. R. & Klett, J. D. *Microphysics of Cloud and Precipitation* (Reidel, Dordrecht, 197
13. Heymsfield, A. J. & Sabin, R. M. *J. atmos. Sci.* **46**, 2252–2264 (1989).
14. Heymsfield, A. J. *J. atmos. Sci.* **34**, 367–381 (1977).
15. Mason, B. J. *The Physics of Clouds* (Clarendon, Oxford, 1957).
16. Somerville, R. C. J. & Remer, L. A. *J. geophys. Res.* **89**, 9668–9672 (1984).
17. Liou, K.-N. & Wittman, G. D. *J. atmos. Sci.* **36**, 1261–1273 (1979).
18. Stephens, G. L. *J. atmos. Sci.* **35**, 2123–2132 (1978).
19. Somerville, R. C. J. & Iacobellis, S. *Am. Met. Soc. 7th Conf. Ocean-Atmos. Interaction* 53–5 (1988).
20. Liou, K.-N. & Ou S.-C. *Preprints of 10th Int. Cloud Phys. Conf.* Vol. II, 118–120 (1988).
21. Schlesinger, M. E. & Mitchell, J. F. B. *Rev. Geophys.* **25**, 760–798 (1987).
22. Hansen, J. E. *et al. Geophysical Monographs Series* Vol. 29, 130–163 (American Geophysic Union, Washington, DC, 1984).
23. Jones, P. D. *et al. Nature* **338**, 790 (1988).

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Disequilibrium silicate mineral textures: fractal and non-fractal features

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IGNEOUS rocks formed from lava flows of the Archaean era (>2,700 million years ago) are often found to contain disequilibrium-textured crystals characterized by spherulitic, branching or dendritic morphologies that occur in layers near the flow surface. Well-known examples are the plagioclase spherulites of basalts and the platy and branching spinnifex-textured olivines and pyroxenes of komatiites[1,2]. Here we present evidence that, over a finite range of length scales, some disequilibrium textures are scale invariant. This observation implies that over this range of length scales their random patterns can be quantitatively characterized by a unique number, the fractal dimension[3]. We also demonstrate that some textures have a crossover from fractal to non-fractal behaviour. It is known that most disequilibrium crystals arise in part from rapid cooling and represent the case where the growth rates of the crystals are large compare to the diffusion rates in the silicate melt[1,2,4]. We therefore formulate a quantitative model for the growth that is based on a variant of diffusion-limited aggregation (DLA)[5].

Figure 1 shows a section of small disequilibrium crystals, at different magnifications. These form close to the quench/glassy margin of some lava flows[6], and their outline remains the same as the microscope objective power is increased. Similar remarks can be made about textures on other length scales, such as the much larger branching pyroxene crystal of Fig. 2*a*.

The concepts and techniques of fractal geometry[3] have proven useful in understanding other random morphologies, in part because a fractal object is characterized quantitatively by a number, the fractal dimension d_f, that relates the increase in mass M of the object to its characteristic length scale L, $M \approx L^{d_f}$ (ref. 7).

To determine d_f we digitized photographs of the textures using a video camera with a grid of 65,536 pixels. First we randomly chose any pixel belonging to the digitized texture. About this 'local origin' we constructed a sequence of concentric shells of

DAB-FYI

Dr. Bromley: 10/13/89

*********OPINION*********

Based upon my listening very hard to both our domestic and international communities (scientific and policy) over the past weeks, I think it is very important for both you and the President to come across as strong supporters for positive and agressive steps to protect the global environment.

Of course, we must proceed with a realistic and careful view of the costs/impacts across the board (industry, etc) but we must appear to be out front environmentally.

Important: There is a risk here that you, OSTP, and the President may appear to be foot-dragging on the issue, when, in fact, we are attempting to shape a careful, prudent, and coordinated US Gov't approach and policy.

I will be meeting with DPC folks this afternoon on the issue but we should talk soon on the entire matter. (Also, on the matter of climate models) N.

Sensible article by Slingo attached on climate models - I think we should use caution in the use or reference to these models. There is no question now that changes will occur. The models present different scenarios of change.

Most agree, however, that we need to respond - we just need to determine the most sensible way to respond as a government.

CLIMATE CHANGE

Wetter clouds dampen global greenhouse warming

Tony Slingo

VARIATIONS in cloudiness can significantly affect the Earth's radiation budget — the absorbed solar energy and the thermal energy radiated back to space[1]. This conclusion is supported by various modelling studies of the 'greenhouse' effects of increased CO_2 concentrations[2-4]. In these studies, the CO_2 forcing induces changes in the cloud coverage and liquid-water content, which alter the radiation budget further and thus modify the original perturbation. On page 132 of this issue[5], Mitchell *et al.* add a new twist to the story, showing how changes in the relative amounts of ice-crystal and water-drop clouds substantially reduce the sensitivity of their model to changes in concentration of CO_2. Indeed, it is becoming apparent that uncertainties in the treatment of clouds severely undermine model prediction of climate.

Mitchell *et al.* used various versions of the UK Meteorological Office atmospheric general circulation model[6] coupled to a 50-m ocean mixed layer[7]. Replacing the standard cloud prediction scheme based on relative humidity by a more sophisticated prescription including liquid water and ice virtually halves the average equilibrium surface warming due to doubled CO_2 — from 5.2 K to 2.7 K. They argue that this spectacular sensitivity to details of the cloud scheme is caused by the replacement of ice clouds by water clouds near the freezing level. In the new cloud scheme, the fall-speed assumed for water drops is much smaller than that for ice crystals, so that liquid-water clouds can dissipate more slowly than ice clouds. According to Mitchell *et al.*, this leads to the predicted relative increase in water clouds near the freezing level, which consequently reduces the amount of solar energy absorbed in the system (more is reflected back into space) and hence gives a smaller warming. When, in addition, cloud radiative properties are allowed to depend on the liquid-water content of clouds, the surface warming drops still further, to only 1.9 K.

The strong dependence of the magnitude of cloud feedback in this work on the details of the model parallels results presented recently[8] by a large *ad hoc* group (including Mitchell and myself) led by Robert Cess of the State University of New York. We compared 14 general circulation models and found a three-fold variation in global climate sensitivity, caused largely by differences in the cloud feedbacks. The models disagreed not only as to the magnitude but also the sign of the net cloud feedback. For this reason, it is clear that uncertainty in how to formulate clouds represents a formidable obstacle to reliable climate prediction.

This underlines the continuing need for physical parameterizations to be compared with results from field studies. This is particularly important now that models are becoming increasingly complex. Mitchell *et al.* argue that the assumptions in their model are 'at least qualitatively realistic', but if climate change simulations are to be believable, then all parts of a model must be validated quantitatively, and important processes that are ignored must be identified. Of particular relevance to the cloud problem is the FIRE programme (first regional experiment of the international satellite cloud climatology project), both in its stratocumulus[9] and cirrus[10] field phases. Several papers are in preparation that highlight the complexity of the mesoscale dynamical structure of cirrus, so that the fall-speed of ice crystals is only part of the story. It is also interesting that two cases of highly supercooled liquid-water altostratus clouds at temperatures around −30 °C were observed (A.J. Heymsfield *et al.*, personal communication), which suggests that the transition from water to ice clouds is more subtle than Mitchell *et al.* assumed for their model.

The substantial sensitivity of climate models to the details of their formulation, and the fact that 14 models give 14 different answers for the cloud feedback, show that we are far from the goal of accurate predictions of future climate change. Sensitivity studies such as that reported by Mitchell *et al.* and comparisons between models as done by Cess *et al.* are now the bread and butter of climate modelling. But at the present rate of progress, it will be several years before reliable predictions of global and regional climate change are available from the models. That underlines the need for comprehensive monitoring that is capable of unravelling the climate change signal from the noise and of providing enough data on the state of the atmosphere, the Earth's radiation budget and clouds for the feedbacks to be determined by observation. Such an analysis may well yield the fifteenth answer but at least it will have come from the real world and will permit a much needed test of the models. □

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1. Ramanathan, V. *et al. Science* **243**, 57–63 (1989).
2. Schlesinger, M.E. & Mitchell, J.F.B. *Rev. Geophys.* **25**, 760–798 (1987).
3. Schlesinger, M.E. *Nature* **335**, 303–304 (1988).
4. Roeckner, E. *Nature* **335**, 304 (1988).
5. Mitchell, J.F.B., Senior, C.A. & Ingram, W.J. *Nature* **341**, 132–134 (1989).
6. Slingo, A., Wilderspin, R.C. & Smith, R.N.B. *J. geophys. Res.* **94**, 2281–2301 (1989).
7. Wilson, C.A. & Mitchell, J.F.B. *J. geophys. Res.* **92**, 13315–13343 (1987).
8. Cess, R.D. *et al. Science* **245**, 513–516 (1989).
9. Albrecht, B.A., Randall, D.A. & Nicholls, S. *Bull. Am. met. Soc.* **69**, 618–626 (1988).
10. Starr, D.O'C. *Bull. Am. met. Soc.* **68**, 119–124 (1987).

ECOLOGY

Just proportions in food webs

Joel E. Cohen

IN FOOD webs of natural communities with varying numbers of species, the number of green plants and other species that consume no prey in the web (basal species) is nearly proportional, on average, to the number of species that have both predators and prey in the web (intermediate species), according to studies reported over the past dozen years[1-4]. Empirical rules[5,6] of that type describe structural or anatomical properties of food webs. An important question in community ecology is whether parallel regularities exist in the way in which food webs function[7,8]. On page 142 of this issue[9], McNaughton *et al.* report remarkable regularities in measures of food web function. Their findings indicate the existence of a physiology of food webs that generalizes across natural communities. Their report opens up the distant, but highly attractive, prospect of linking the previously known structural regularities with new functional patterns.

McNaughton *et al.* show that the biomass, consumption and net secondary productivity (NSP) of herbivores are all related to the net above-ground primary productivity (NAP) of a natural habitat by simple power laws. Particularly striking is that the exponent of the power law that relates NSP to NAP is not significantly different from 1: to a first approximation, NSP and NAP are directly proportional. In effect, the energy converted into herbivores per square metre of surface area per year is, on average, about one-thousandth of the energy that is converted into plants per square metre of surface area per year. The ecological energy pyramid has a much larger base than second storey.

This proportionality would be a triviality if secondary productivity were passively controlled and limited by primary productivity. But this trickle-down view of

TABLE 2 Newtonian error and signal strength

	Maximum 1-μm shape error		Fifth force	
Distance r (m)	Displacement f^2S (m s^{-2})	Strain f^2h (s^{-2})	Displacement $f^2S\lambda^2/\alpha$ (m^3 s^{-2})	Strain $f^2h\lambda^2/\alpha$ (m^2 s^{-2})
2	4×10^{-18}	2×10^{-17}	1.1×10^{-13}	3×10^{-13}
4	1.3×10^{-19}	3×10^{-19}	1.4×10^{-14}	2×10^{-14}
8	4×10^{-21}	5×10^{-21}	1.8×10^{-15}	1.3×10^{-15}

The results detailed here show that it may be feasible to use the asymmetric monopole to test the fifth-force hypothesis, although the experiment is obviously not easy, and practical problems remain to be examined in detail. For example, there are small elastic distortions in a rotating body as a result of centrifugal forces. The shape defined by Table 1 is the shape that must be achieved at the final rotation speed. A numerical calculation would give the correct initial shape for a given material. Advantages of the experiment are that the experiment is a null one and one can adjust the shape to find the null, and that only octupole-patterned deformations give rise to error signals as large as in Table 2. Also, the parameters I have chosen (size, distance, tolerance and material) are nominal. There is also the possibility that a refinement of this idea, or an incorporation of the mathematical idea into other experimental techniques (such as torsion balances) may prove effective. I note that the experiment would not depend on any variation of the fifth force with chemical composition, as do many of the recent experiments. □

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1. Sinsky, J. A. *Phys. Rev.* **167**, 1145–1151 (1968).
2. Hyrakawa, K. & Kuroda, K. *Phys. Rev.* D**32**, 342–346 (1985).
3. Stubbs, C. W. *Nature* **338**, 301–302 (1989).
4. Stacey, F. D. *et al. Rev. Mod. Phys.* **59**, 157–174 (1987).
5. Duff, G. F. D. & Naylor, D. *Differential Equations of Applied Mathematics* 356 (Wiley, New York, 1966).
6. Ward, H. *et al.* Proc. Int. Symp. Expl. Gravitational Phys. (eds Michelson, P. F., Hu, E.-L. and Pizzella, G.) 322–327 (World Scientific, Singapore, 1988).
7. Del Fabbro, R. *et al. Phys. Lett.* A**124**, 253–257 (1987).
8. Del Fabbro, R. *et al. Phys. Lett.* A**132**, 237–240 (1987).
9. Thorne, K. S. in *300 Years of Gravitation* (eds Hawking, S. W. & Israel, W.), 330–458 (Cambridge University Press, 1987).

ACKNOWLEDGEMENTS. I thank G. Gibbons for discussions about the fifth force, J. Hough for discussions about gravity-wave detectors and M. Hindmarsh for practical help.

CO_2 and climate: a missing feedback?

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THE potential of changes in cloud properties to modulate climate perturbations is well known[1,2]. Changes in cloud amount and cloud height[3], cloud radiative properties[4–6] and cloud condensation nuclei[7] (CCN) have all been recognized as possible sources of climate feedbacks. Here we report results of simulations that indicate that the changes of state of cloud water may provide a substantial negative feedback on climate. The feedback is concentrated in mid-latitudes and affects both the magnitude and distribution of the climate change expected from increases in 'greenhouse' gases. Improved measurements and parameterizations of cloud processes are needed to quantify this process.

The model is an 11-level atmospheric general-circulation model on a 5°×7.5° (latitude×longitude) horizontal grid coupled to a 50-m mixed-layer ocean with a prescribed seasonally and geographically varying oceanic heat convergence to represent heat advection by ocean currents[8]. In the standard model[8] cloud cover is a function of relative humidity. A second version of the model was constructed with an explicit cloud-water variable for all but deep convective cloud[9]. A balance is maintained between cloud water content and water vapour, which is altered by dynamical, convective and boundary-layer processes. Cloud water content is depleted by precipitation at a rate dependent on the phase of the cloud water, which is a function of the local temperature of the layer. For water cloud the rate of conversion to precipitation increases as a function of the in-cloud water content and is marginally enhanced in the presence of precipitation from higher layers. The transition from water cloud to ice cloud occurs between −15 °C and 0 °C as a smoothly varying function of temperature. Ice-cloud particles are assumed to start falling as soon as they form, with a fixed fall speed of 1 m s^{-1}. The rate of precipitation of ice is, on average, an order of magnitude greater than that of water even in the presence of precipitation from the layer above. Cloud radiative properties were prescribed. Note that although the revised cloud scheme is more detailed, it is not necessarily more accurate than the less sophisticated scheme. Our work highlights how different parameterization schemes can affect the sensitivity of the climate to CO_2.

Two simulations, with CO_2 concentrations of 320 and 640 p.p.m., were performed for each version of the model. The results shown here are averaged over five years after the simulations reached equilibrium. On replacing the relative-humidity cloud scheme[8] (henceforth referred to as RH) with the model based on cloud water content[9] (CW), the global annual average surface warming is reduced from 5.2 K to 2.7 K. The largest fractional reduction in the warming occurs in higher latitudes (Fig. 1*a*) where the large decreases in total cloud cover with RH have been replaced by much smaller reductions or slight increases (Fig. 1*b*).

With RH, reductions in cloud cover are found throughout the depth of the mid-latitude troposphere (Fig. 2*a*), as in earlier studies[3]. With CW, the main differences in response occur near the freezing level (Fig. 2*b*) where, in the warmer doubled-CO_2

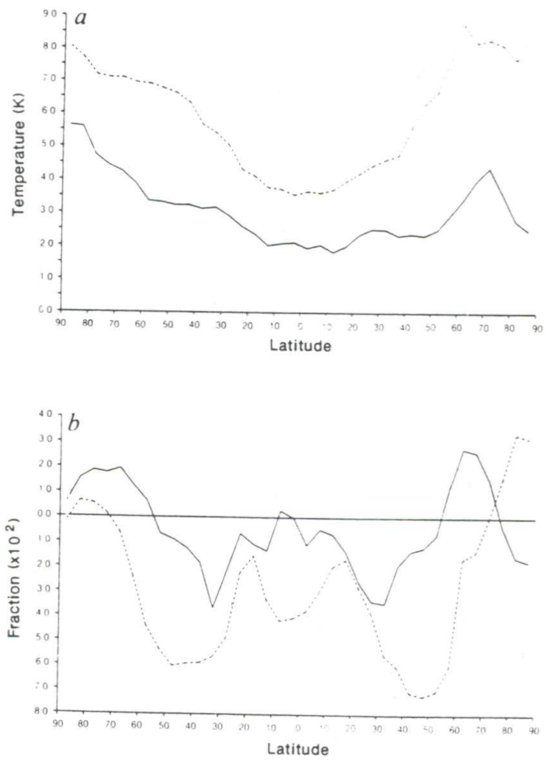

FIG. 1 Zone-averaged equilibrium changes in *a*, surface temperature and *b*, fractional cloud cover on doubling CO_2 (five-year means). Solid line, simulation with CW. Dashed line, simulation with RH.

simulation, ice cloud which is depleted rapidly by precipitation is replaced by water cloud which is depleted more slowly, so that cloud cover increases. This can be seen more clearly in the height-latitude distribution of the changes in cloud liquid water and cloud ice (Fig. 3). Also shown are the mean 0 °C and −15 °C isotherms in the control simulation. Because of the increases in cloud, the enhanced absorption of solar radiation in mid-latitudes found with RH is greatly reduced when using CW (Fig. 4).

One can define a climate sensitivity parameter λ ($=\Delta Q/\Delta T$) where ΔQ is the change in radiative heating at the tropopause on doubling CO_2 and ΔT is the equilibrium change in surface temperature. Assuming[10] $\Delta Q = 4\ \mathrm{W\,m^{-2}}$, λ is increased from 0.77 to 1.48 $\mathrm{W\,m^{-2}\,K^{-1}}$ on replacing RH by CW. Thus changes in the phase of cloud water provide a strong negative feedback on climate, cancelling almost all the previous strong positive feedback from cloud in RH[11]. Although our model does not allow for this process in deep convective clouds, these have a small areal coverage and a relatively high liquid-water content, however, suggesting that any radiative feedback from this type of cloud would be small.

The lower-cloud increases in the simulations arise from the assumption that under similar conditions ice is removed more efficiently from cloud than water. In real water clouds, relatively few droplets become large enough to fall out, as the available condensed water is spread over many cloud condensation nuclei (CCN)[12]. Very few CCN act as ice nuclei[13], so in ice clouds the cloud water is spread over fewer, larger particles, all of which have appreciable fall speeds[14]. The microphysics of mixed-phase clouds are complex and not fully understood. Although our model does not explicitly represent them it effectively includes their most important aspect, the continual rapid conversion of water to ice[15]. A more complex representation would certainly change the pattern in Fig. 2 locally, but the vertically integrated response would probably depend primarily on the overall change from pure ice cloud to pure water cloud. Thus our assumptions concerning the relative fall-out of ice and water are at least qualitatively realistic.

As 1 $\mathrm{m\,s^{-1}}$ may be a large value for ice fall speed, we have rerun experiment CW using a parameterization of fall speed in terms of ice-water content based on observations[14] (experiment CWH). For typical simulated ice-water contents, this gives fall speeds of 0.2 $\mathrm{m\,s^{-1}}$ for high ice cloud and 0.7 $\mathrm{m\,s^{-1}}$ for ice cloud near the freezing level. Cloud changes (Fig. 2*c*) are qualitatively similar to Fig. 2*b* and the global warming is 3.2 K, only slightly larger than in CW. The similarity between CW and CWH is to be expected, given that the depletion rate of ice relative to water is large near the freezing level in both experiments.

It has recently been suggested that changes in cloud radiative properties may contribute an important feedback to climate[4,5,16]. In a warmer climate, greater cloud water content would increase cloud albedos (a negative feedback) and emittances (a positive feedback). A further experiment was carried out using the revised version of the model with an additional modification to

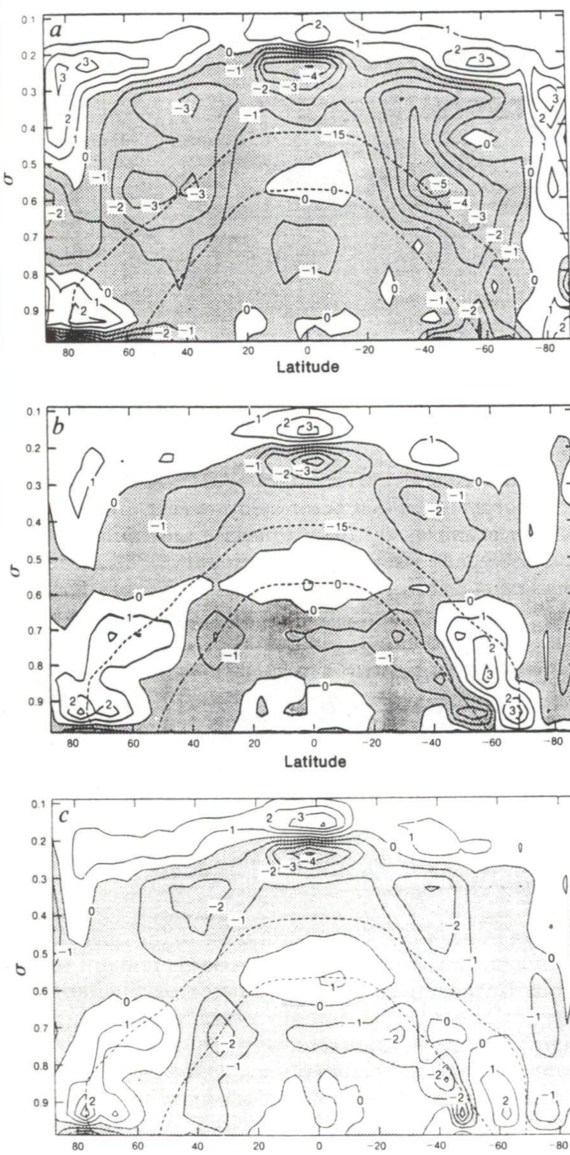

FIG. 2 Height–latitude cross-section of equilibrium changes in cloud amount on doubling CO_2. The height coordinate is σ (pressure/surface pressure). Areas of reduction are stippled and the contours are every 1%. The dashed lines are the 0 and −15 °C contours from the control simulation. *a*, Simulation with RH. *b*, Simulation with CW. *c*, Simulation with CWH.

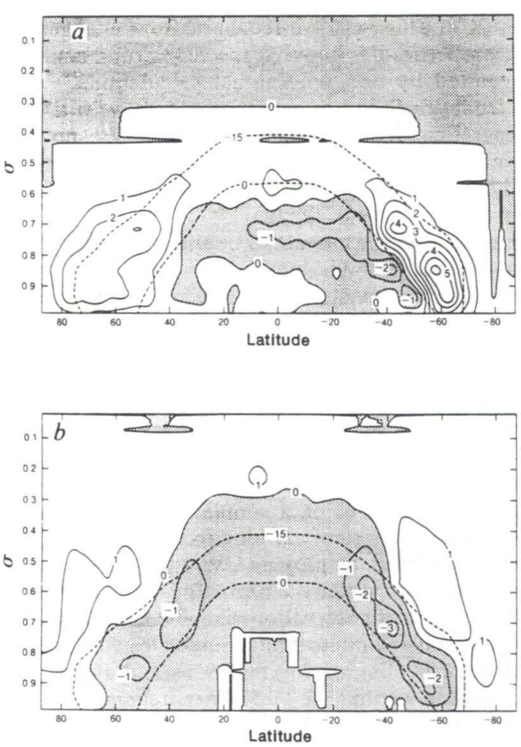

FIG. 3 Height–latitude cross-section of equilibrium changes in cloud water in CW on doubling CO_2. The height coordinate is σ. Areas of reduction are stippled. The dashed lines are the 0 and −15 °C contours from the control simulation. *a*, Liquid-water content only. Contours every $4\times10^{-6}\ \mathrm{kg\,kg^{-1}}$. *b*, Ice-water content only. Contours every $4\times10^{-7}\ \mathrm{kg\,kg^{-1}}$.

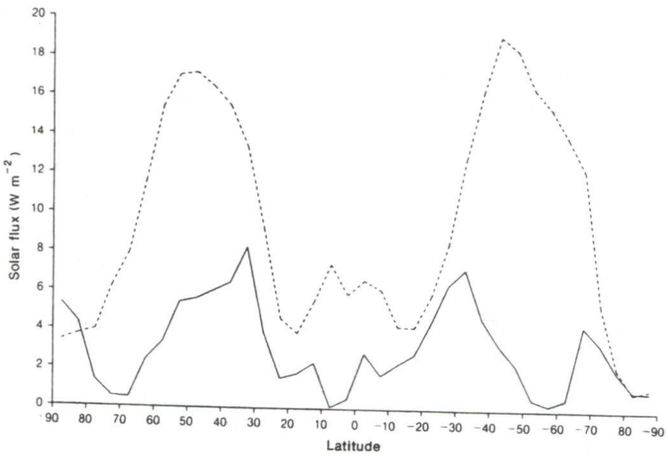

FIG. 4 Zone-averaged equilibrium change in net solar flux at the top of the atmosphere on doubling CO_2 (five-year mean). Solid line, simulation with CW. Dashed line, simulation with RH.

allow the cloud radiative properties to depend on the cloud water content (scheme CWRP). (Given the similarity between CW and CWH, this experiment was carried out with the CW formulation only.) Analytical fits of the short-wave albedo and transmittance as functions of cloud-water path and solar zenith angle were made to a published scheme[17] based on observations and theoretical considerations. The long-wave flux emittance was given by $(1-\exp(-\kappa q))$ where q is the condensed-water path and $\kappa = 0.13\ \mathrm{m^2\ g^{-1}}$ for water clouds and $0.065\ \mathrm{m^2\ g^{-1}}$ for ice clouds[18].

On doubling the CO_2 concentrations the global annual average equilibrium surface temperature increased by 1.9 K with CWRP compared to 2.7 K with prescribed cloud radiative properties (CW), indicating a further increase in λ to $2.1\ \mathrm{W\ m^{-2}\ K^{-1}}$. This negative feedback from changes in cloud radiative properties lies between the very strong negative feedback suggested by one-dimensional calculations[16,19] and the positive feedback found in a previous study with a low-resolution general-circulation model (GCM)[4-6]. We note that all existing numerical studies assume that the number of CCN remains constant under climate change. Changes in CCN are a further possible source of feedback[7,20].

The sensitivity of the climate to doubling the CO_2 concentrations that we have found is substantially smaller than the 4-5 K found in other recent studies[10,21]. A significant part of this reduction in sensitivity is due to the different cloud scheme. If correct this will have two important consequences. First, the equilibrium warming expected from the estimated $2\ \mathrm{W\ m^{-2}}$ increase in radiative heating at the tropopause since 1860 (ref. 9) will be smaller. Second, the proportion of the equilibrium reached will be greater, because the thermal response time of the climate system is reduced if climate sensitivity is reduced[22]. Based on calculations using a simple one-dimensional model of the ocean, the expected warming to date, using the climate sensitivity found when employing CW, is 0.6 K. This is close to the observed warming since the beginning of the century (0.5 K; ref. 23). The record of observations shows considerable variability on interannual and interdecadal timescales, however, including a period of cooling during the 1950s and 1960s, so that it is not possible to attribute the 0.5 K rise unambiguously to the effect of increases in trace gases. □

Received 14 June; accepted 14 August 1989.

1. Manabe, S. & Wetherald, R. T. *J. atmos. Sci.* **24**, 241–259 (1967).
2. Schneider, S. H. *J. atmos. Sci.* **29**, 1413–1422 (1972).
3. Wetherald, R. T. & Manabe, S. *J. atmos. Sci.* **45**, 1397–1415 (1988).
4. Roeckner, E. *et al. Nature* **329**, 138–140 (1987).
5. Roeckner, E. *Nature* **335**, 304 (1988).
6. Schlesinger, M. E. *Nature* **335**, 303–304 (1988).
7. Charlson, R. J. *et al. Nature* **334**, 418–420 (1988).
8. Mitchell, J. F. B. & Warrilow, D. A. *Nature* **330**, 238–240 (1987).
9. Smith, R. N. B. *Q. Jl R. met. Soc.* (in the press).
10. Dickinson, R. E. & Cicerone, R. J. *Nature* **319**, 109–115 (1985).
11. Wilson, C. A. & Mitchell, J. F. B. *J. geophys. Res.* **92**, 13,315–13,343 (1987).
12. Pruppacher, H. R. & Klett, J. D. *Microphysics of Cloud and Precipitation.* (Reidel, Dordrecht, 1978
13. Heymsfield, A. J. & Sabin, R. M. *J. atmos. Sci.* **46**, 2252–2264 (1989).
14. Heymsfield, A. J. *J. atmos. Sci.* **34**, 367–381 (1977).
15. Mason, B. J. *The Physics of Clouds* (Clarendon, Oxford, 1957).
16. Somerville, R. C. J. & Remer, L. A. *J. geophys. Res.* **89**, 9668–9672 (1984).
17. Liou, K.-N. & Wittman, G. D. *J. atmos. Sci.* **36**, 1261–1273 (1979).
18. Stephens, G. L. *J. atmos. Sci.* **35**, 2123–2132 (1978).
19. Somerville, R. C. J. & Iacobellis, S. *Am. Met. Soc. 7th Conf. Ocean-Atmos. Interaction* 53–5 (1988).
20. Liou, K.-N. & Ou S.-C. *Preprints of 10th Int. Cloud Phys. Conf.* Vol. II, 118–120 (1988).
21. Schlesinger, M. E. & Mitchell, J. F. B. *Rev. Geophys.* **25**, 760–798 (1987).
22. Hansen, J. E. *et al. Geophysical Monographs Series* Vol. 29, 130–163 (American Geophysica Union, Washington, DC, 1984).
23. Jones, P. D. *et al. Nature* **338**, 790 (1988).

ACKNOWLEDGEMENTS. We would like to thank R. Smith who devised and wrote the cloud wate scheme used.

Disequilibrium silicate mineral textures: fractal and non-fractal features

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† Center for Polymer Studies and Department of Physics, Boston University, Boston, Massachusetts 02215, USA
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IGNEOUS rocks formed from lava flows of the Archaean era (>2,700 million years ago) are often found to contain disequilibrium-textured crystals characterized by spherulitic, branching or dendritic morphologies that occur in layers near the flow surface. Well-known examples are the plagioclase spherulites of basalts and the platy and branching spinnifex-textured olivines and pyroxenes of komatiites[1,2]. Here we present evidence that, over a finite range of length scales, some disequilibrium textures are scale invariant. This observation implies that over this range of length scales their random patterns can be quantitatively characterized by a unique number, the fractal dimension[3]. We also demonstrate that some textures have a crossover from fractal to non-fractal behaviour. It is known that most disequilibrium crystals arise in part from rapid cooling and represent the case where the growth rates of the crystals are large compare to the diffusion rates in the silicate melt[1,2,4]. We therefore formulate a quantitative model for the growth that is based on a variant of diffusion-limited aggregation (DLA)[5].

Figure 1 shows a section of small disequilibrium crystals, at different magnifications. These form close to the quench/glassy margin of some lava flows[6], and their outline remains the same as the microscope objective power is increased. Similar remarks can be made about textures on other length scales, such as the much larger branching pyroxene crystal of Fig. 2*a*.

The concepts and techniques of fractal geometry[3] have proven useful in understanding other random morphologies, in part because a fractal object is characterized quantitatively by a number, the fractal dimension d_f, that relates the increase in mass M of the object to its characteristic length scale L, $M \approx L^{d_f}$ (ref. 7).

To determine d_f we digitized photographs of the textures using a video camera with a grid of 65,536 pixels. First we randomly chose any pixel belonging to the digitized texture. About this 'local origin' we constructed a sequence of concentric shells of

THE WHITE HOUSE

WASHINGTON

September 20, 1989

MEMORANDUM FOR JOHN SUNUNU
CHIEF OF STAFF TO THE PRESIDENT

FROM: D. ALLAN BROMLEY
ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY

SUBJECT: GLOBAL ENVIRONMENTAL CHANGE

Enclosed herewith is a memorandum for the President on this topic in which I make the suggestion for a meeting of senior scientific representatives that I discussed very briefly with you on Tuesday.

Immediately after our discussion I met with the delegation from the British Houses of Commons and of Lords. During the discussion I floated the idea of this meeting and, at least in this group, met with a very enthusiastic response.

I recognize fully that there may be many other factors that will decide how best the President should follow up on what has come to be considered, in many quarters, his promise to host a Summit on the global environment.

My goals are a) to insure that the Summit, when it occurs, can show concrete results and b) that either by design or inadvertence it not be to closely focussed on global <u>warming</u> as some would like it.

THE WHITE HOUSE

WASHINGTON

December 1, 1989

Dear Bill:

Many thanks for your note of November 8 and your "Sixteen Theses on the Greenhouse Effect." You quite correctly assume that I am in the middle of the global warming problem, having been asked by the President to chair the Domestic Policy Council Working Group on that subject, charged with developing the formal U.S. government policy on the matter. As you are also quite aware, there has been a wide divergence of opinion, and the task of pulling this together into a coherent policy is anything but a simple one.

Your input is particularly valuable, because I have asked Mike Boskin and his folk in the Council of Economic Advisers to take on the task of quantifying, in an economic sense, the impact of postulated scenarios for global warming as the basis for the development of some reasonable policies. In parallel with that, I have also asked the Department of the Interior to coordinate the collection of input from the private industrial sector, a group that has substantial experience, expertise and data in the area but which has been remarkably absent from the discussion thus far, and I have also asked the Justice Department, together with the State Department, to take a look at the kind of framework agreement that we might eventually be prepared to sign. My impression has been that all too frequently in the past we have tended to get shafted in international agreements because we have not done adequate homework before the fact and during the actual negotiations have frequently tended to be nice guys, to our eventual cost. In parallel with these activities, we are meeting with groups of scientists actively working in the field, with groups of economists who have been looking at the area, because there is an impressive divergence of opinion within the economic community and, finally, with groups of spokespersons for the most visible environmental groups. My intent is that with these activities proceeding in parallel with the United Nations activities, under the Intergovernmental Panel on Climate Change, we should be prepared by the latter part of

1990 to discuss the sort of quantitative schedules and possible stabilization and reduction of greenhouse emissions that an amazing fraction of the seventy nations represented at the recent Noordwijk conference were prepared to commit themselves to in the absence of any clear understanding of either the technology required or the economic consequences of their commitments.

As you well know from your own experience in Washington, there are a great many things that one does not discover prior to arriving on the scene, but at least I am learning that one can be beaten about head and shoulders for all manner of things beyond global warming, with technology policy being a marvelous followup.

I am enclosing herewith for your possible interest a set of conclusions that I jotted down on the plane on the way back from the Noordwijk conference early in November that I have subsequently passed on to the President.

Although the press has been making much of the fact that Bill Reilly and I are in opposing camps on these global warming questions, we in fact have been working rather closely together and, as a good Class of '64 Yalie, I find him to be a very able and persuasive colleague.

With all best wishes,

Sincerely yours,

Allan

D. Allan Bromley
Assistant to the President
for
Science and Technology

Enclosure

Professor William D. Nordhaus
Department of Economics
Yale University
P.O. Box 1972 Yale Station
New Haven, Connecticut 06520-1972

THE SECRETARY OF HEALTH AND HUMAN SERVICES
WASHINGTON, D.C. 20201

OCT 16 1989

Mr. D. Allan Bromley
Assistant to the President for
Science and Technology
The White House
Washington, D.C.

Dear Mr. Bromley:

Thank you for your letter endorsing Dr. Bernadine Healy for the position of Director, National Institutes of Health here in the Department of Health and Human Services.

The need to attract highly-qualified individuals here in the Department is great. Dr. Healy's resume is quite impressive. Please be certain that she will be given careful and thorough consideration as I review applications for this position.

Again, thank you for providing me with the name of a candidate that you feel would be an asset to the Department.

With warm regards.

Sincerely,

Louis W. Sullivan

Louis W. Sullivan, M.D.
Secretary

"CORRESPONDENCE TRACKING"

TYPE: Action Item DOCUMENT NUMBER: 8920380

****

FROM: WILLIAM D. NORDHAUS
YALE UNIVERSITY

TO: BROMLEY

DATE OF
CORRESPONDENCE: 11/08/89

SUBJECT: ENCLOSING A COPY OF A SUMMARY DONE FOR THE COUNCIL
ON ECONOMIC ADVISORS FOR YOUR INFORMATION.

****

ASSIGNED TO: D. Allan Bromley

ACTION REQUIRED: ACKNOWLEDGE

****

SENDER'S DUE DATE: OSTP DUE DATE: 12/04/89

DATE COMPLETED: --------

****

COPIES TO: Nancy Maynard

****

REMARKS:

DATE RECEIVED: 11/15/89 FILE: NEOB

Yale University

Department of Economics
P.O. Box 1972 Yale Station
New Haven, Connecticut 06520-1972

Campus address:
28 Hillhouse Avenue

Dr. D. Allan Bromley
President's Science Adviser
Executive Office Building
Washington, D. C.

November 8, 1989

Dear Allan:

You new duties undoubtedly are involving you in the hot issue of global warming. In this regard, I thought you might be interested in a summary that I recently prepared for your colleagues in the Council of Economic Advisers.

I trust you are well. Things are temporarily calm here.

Sincerely yours,

Bill

William D. Nordhaus

THE WHITE HOUSE

WASHINGTON

September 20, 1989

MEMORANDUM FOR THE PRESIDENT

FROM: D. ALLAN BROMLEY DAB

SUBJECT: HEAD OF STATE MEETING ON THE GLOBAL ENVIRONMENT

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

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

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

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

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

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

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

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

I would welcome your guidance and comments.