Nucl. Winter

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20506

November 29, 1984

MEMORANDUM FOR G. A. KEYWORTH

FROM: MAURIE ROESCH Very Respectfully Maurie

SUBJECT: BRIEFING MEMORANDUM - Meeting with Tony Calio and Allen Hecht of NOAA on Friday, November 30, at 1:00pm

PURPOSE: To discuss the draft Nuclear Winter Research Plan

BACKGROUND: This meeting will provide you an informal briefing on the projected scientific research plan for Nuclear Winter. More importantly it will allow us to address several key issues related to Nuclear Winter. These issues are addressed in the agenda below.

PARTICIPANTS:

NOAA: Tony Calio
Allen Hecht

NSC: Bob Linhard

OSTP: Ralph DeVries
Maurie Roesch
Michael Havey

Agenda for the Meeting:

	ITEM	PARTICIPANT
1.	Background	Maurie Roesch
2.	Statement of need for the research from the National Security stand point.	Bob Linhard
3.	Informal brief on the Scientific Research Plan to include expected results, costs, and which agencies would conduct research (see attachment)	Allen Hecht

Agenda for the Meeting (cont.)

ITEM	PARTICIPANT
4. Discussion of Research Program Management Options	Maurie Roesch
5. Discussion of funding approach	Maurie Roesch
6. Review of their action items	Bob Linhard Maurie Roesch
7. Guidance and Direction	Dr. Keyworth

Background Information: Please see attached memo - from Sam Wyman and Maurie Roesch.

BREAKOUT OF FUNDING

FOR

NUCLEAR WINTER RESEARCH BY AGENCY

AGENCY	PERCENTAGE
DoD	25%
DOE	20%
NOAA	10%
NASA	08%
NSF	20%
NBS	12%
NFS	05%

NOTES

1. Based on an annual budget of $7.5M
2. Universities would receive approximately 25%

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November 29, 1984

MEMORANDUM FOR JAY KEYWORTH

THROUGH: MAURIE ROESCH Maurie

FROM: SAM WYMAN MAR III for SW

SUBJECT: Nuclear Winter Update

Tony Calio, Acting Administrator, NOAA, and Allen Hecht, National Climate Project Office (NCPO), will informally brief you on the Nuclear Winter research plan on Friday 30 November. The following items are presented to support your discussion:

- Event Schedule: This document outlines major Nuclear Winter milestones over the next six months. (See Attachment 1)

- Research Program Management Options: A set of Program Management Options are provided for your consideration. (See Attachment 2)

- Budget Breakout and Expected Results: Projected funding elements for 7.5M a year research effort and related science questions answered are presented. (See Attachment 3)

- Information Dissemination Plan: A draft plan for the dissemenation of Federal Government policy and positions related to Nuclear Winter research is provided. (See Attachment 4)

- Action Items Status: The current status of the various action items related to Nuclear Winter are presented. (See Attachment 5)

Attachments

ATTACHMENT 1

Subject: Nuclear Winter Research Program Event Schedule

	Event	Date	Comment
a.	Informal presentation of NCPO plan to OSTP	30 Nov 84	NOT a media event
b.	National Academy of Sciences' (NAS) press release of their study on "The Effects on the Atmosphere of a Major Nuclear Exchange"	11 Dec 84	NCPO will ensure no "surprises" in NAS' press release; governmental agencies will have appropriate Q's and A's
c.	Projected date of Official White House acceptance of NCPO Nuclear Winter Study Plan and statement of Administration's program to include:	mid-Jan 85 (week of 14 Jan 85)*	OSTP will accept. Plan hand-out to press; updated press releases and Q's and A's for State Department, Embassies, and other Government agencies.
	1) Budget		
	2) Management (which agency--pre-brief to ensure continuity)		
	3) Schedule		
	4) Goals		
	5) Review proces		
	6) Release of findings		
	7) International Cooperation		
d.	Congressional Hearings; DoD already requested to testify, expect OSTP and/or management agency of Administration's program to testify	Mar 85	Coordinate testimony with DoD

*NCPO will be involved in other meetings the weeks of 7, 21, and 28 Jan 85.

Attachment #1

ATTACHMENT 2

Management Options for Nuclear Winter Research

Agency/Organization	Features (+)	Features (-)
DoD/DOE	° Responsibility for Nuclear research ° Access to classified/ unclassified data and studies ° Experience ° Available resources/ ease of funding	° National & international perception of bias ° Hesitation of scientific community in dealing with DoD/DOE
Civilian Agency	° Neutralizes bias issue ° Increase technical base ° Facilitate interagency coordination	° Puts agency in "hot seat" ° Impact on agency programs/ mission ° Learning experience (except for DOC) ° No funds
Research Center	° Public credibility ° Non-government scientific management	° Diffuse government responsibility ° No replacement for intergovernmental coordination ° Lose accountability ° Logistics
OSTP	° Access to technical resources ° Promote interagency coordination	° Too close to Administration ° No "management history" ° Change role of OSTP
Interagency Office	° No single agency in spot light ° Neutralize bias ° Allow effective coordination ° Provide broad scientific and technical expertise ° Insulate other agency programs from proposed effort	° Method of budgeting ° Interagency office assigned to agencies
Joint Program Management Office (JPMO) (NCPO, DOE, DoD)	° Available resources/ ease of funding ° Experience ° Allow effective coordination ° Neutralize bias ° Provide broad scientific and technical expertise ° No single agency in spot light	° NCPO is within another agency

Recommendation

Key requirements, necessary for management of programs, are:

- Access to information
- Credibility
- Increase technical base
- Effective coordination
- Adequate funding mechanisms/accountability

Based on the above, the JPMO is the recommended management option.

The JPMO should be headed by the Director of NCPO with representation of DoD and DOE. The JPMO will manage and coordinate Nuclear Climate research represented by on-going DoD and DOE programs and the Administration's National Nuclear Climate Program. Administration of the funding for the national program should be through the DoD. The JPMO should be chartered by OSTP.

EXPECTED RESULTS OF RESEARCH PROGRAM

ISSUES	EXPECTED RESULTS (1985 -1986)*
HOW MANY FIRES? WHERE?	REPRESENTATIVE TARGET DATA AVAILABLE FOR MODELING STUDIES.
HOW MUCH SMOKE? WHAT KINDS?	STATISTICAL DATA BASE FOR TARGET AREAS PROGRAM PLAN FOR EXPERIMENTAL STUDIES.
WHERE DOES SMOKE GO? (THEORY) (EXPERIMENT)	EXPANDED THEORETICAL STUDIES. IMPROVED MODELS TO INCLUDE CLOUD- H_2O-ICE PARAMETERIZATION. PLAN FOR FIELD STUDIES.
OPTICAL PROPERTIES OF SMOKE?	EXPANDED THERORETICAL AND EXPERIMENTAL STUDIES TO BETTER DEFINE PHYSICAL PROPERTIES OF SMOKE.
MESOSCALE PHENOMENA	EALUATION OF EXISTING CLOUD AND PLUME MODELS. INITIAL DEFINITION OF KEY MESOSCALE PROCESSES
GLOBAL SCALE PHENOMENA	IMPROVED ESTIMATES OF CLIMATE EFFECTS BASED ON MODEL UPGRADES.
BIOLOGICAL CONSEQUENCES	ASSESSMENT STRATEGY.
TOXICOLOGY AND CHEMISTRY	ASSESSMENT OF POTENTIAL EFFECTS, PLAN FOR FUTURE WORK.

* BASED ON BUDGET OF $7.5M

Attachment #3

PROPOSED INITIAL INCREASE OF FUNDS
FOR NUCLEAR CLIMATE RESEARCH (OPTION 2)

ISSUES	STATUS OF EXISTING PROGRAM	$K BUDGET (FY85) EXISTING	INCREASE	TOTAL
HOW MANY FIRES? WHERE?	ADEQUATE EFFORT; NEED TARGET AREAS	150	-0-	150
HOW MUCH SMOKE? WHAT KINDS?	WIDE RANGE OF ESTIMATES; INADEQUATE EXPERIMENTAL DATA	450	400	850
WHERE DOES SMOKE GO? (THEORY)	INADEQUATE THEORETICAL STUDIES	700	750	1450
(EXPERIMENT)	NONE	-0-	500	500
OPTICAL PROPERTIES OF SMOKE?	INADEQUATE DESCRIPTION OF PHYSICAL PROPERTIES OF SMOKE; NEED EXPERIMENTAL STUDIES	500	550	1050
MESOSCALE PHENOMENA	INADEQUATE MODELING	500	850	1350
GLOBAL SCALE PHENOMENA	FIRST ORDER MODELING DONE; NEED COMPREHENSIVE MODEL UPGRADE	1050	550	1600
BIOLOGICAL CONSEQUENCES	NEEDS INITIAL ASSESSMENT AND RESEARCH PLAN	50	100	150
TOXICOLOGY AND CHEMISTRY	NEEDS ASSESSMENT; POTENTIAL SERIOUS PROBLEM	100	300	400
		3500	4000	7500

Attachment #3

Subject: Nuclear Winter Research Program Information Dissemination Plan (IDP)

a. Prepare for NAS' release of Nuclear Winter study on 11 December.

(1) Q's &A's to be developed by DNA for policy group consideration appropriately augumented and distributed to Government agencies (Embassies also). A. Hecht recommended that CO_2 report release format be used as a model.

Complete by - 30 Nov 84

Responsible Agency - DNA to prepare, Policy Committee to distribute by 7 Dec 84

(2) NCPO prepare and coordinate with policy committee a government statement on NAS' press release to reflect:

(a) Interagency group reviewing NCPO draft science plan,

(b) Expect formal presentation of plan to the White House in mid-January and announcement of government program.

Complete by - 30 Nov 84

Responsible Agency - NCPO

b. Update Q's and A's and information papers to reflect questions and concerns raised in NAS' press release.

Complete by - 14 Dec 84

Responsible Agency - NCPO/DNA/OSTP

c. Prepare acceptance statement of NCPO plan, announcement of the Administration's program, and update Q's and A's. The announcement of the Administration's program should also include release of the "science research objectives" of the NCPO plan (Sections 3, 4, and 5).

Complete by - 4 Jan 84

Responsible Agency - OSTP

Attachment #4

d. Prepare Congressional testimony as required. Is advanced Congressional notification of Administration's program appropriate? Who is contact? When? Testimony should be prepared in collaboration with DoD to ensure "one voice." Testimony may be required by the White House Staff and/or the management agency for the Administration's program.

Complete by - as required

Responsible Agency - To be assigned

Nuclear Winter

Information Dissemination Plan (IDP)

Action Items List

	Action	Responsibility	Status
1.	Read NAS' study to ensure no surprises at press release	NCPO	Due 23 Nov 84
2.	Coordinate DNA's preparation of Q&A's to support IDP (Milt Gillespie is DNA POC)	OSTP	DNA's Q&A's due 30 Nov
3.	Distribute approved Q&As/ information papers to agencies after Policy Committee review prior to NAS press release on 11Dec	OSTP/NCPO	Due 7 Dec 84
4.	Background Information Packet		
	a. Information Paper	NCPO	Due 7 Dec 84
	b. Collection of Press Clippings, Magazines, etc.	NCPO/OSTP	Ongoing
	c. Executive Summary of NAS' Study	NCPO	ASAP
	d. Executive Summary Plan	NCPO	7 Dec 84
5.	Prepare statement on NCPO science plan for release at NAS' press conference	NCPO	Due 30 Nov 84
6.	Update Q&As after NAS' press conference to reflect concurrence/ questions	NCPO/DNA/OSTP	Due by 14 Dec
7.	Prepare press handout and Q&As for formal NCPO plan acceptance by OSTP	OSTP	Due 4 Jan 85
8.	Prepare Congressional testimony as required in collaboration with DOD	OSTP	As Required

Attachment #5

20 November 84

SUBJECT: Nuclear Winter Action Item List

	Action	Responsibility	Status
1.	A. Hecht to brief OSTP, DOS and NSC on historical and international interactions and possible future events	NCPO	By 07 Dec 84
2.	Determine U.S. posture in international forums and prepare paper for policy committee, includes possible involvement in cooperative (bi-lateral) research	DOS/ACDA	By 27 Nov 84
3.	Determine Soviet intentions in international forums and why.	DOS/IC Staff	Working
4.	Develop public affairs plan for media	OSTP	By 07 Nov 84
5.	Identify budget approach for research program	OMB/NSC/OSTP	By 15 Dec 84
6.	Coordinate draft Science Research Program Plan for submission to White House (OSTP)	OMB/OSTP/NOAA	By 30 Nov 84

Attachment #5

Nucl. Winter

CORNELL UNIVERSITY

Center for Radiophysics and Space Research

SPACE SCIENCES BUILDING
Ithaca, New York 14853 - 0355

Telephone (607) 256-4971

Laboratory for Planetary Studies

6 November 1984

Dr. George A. Keyworth
Science Advisor to the President
The White House
Washington, DC

Dear Dr. Keyworth:

Thank you for your letter of October 9th. Studies of the policy implications of Nuclear Winter could be parameterized in the same way that the physical and biological studies are parameterized: Let the uncertainties vary over their plausible range, and see what policy implications emerge for the various parameter choices. This is already the procedure being pursued by Department of Defense studies, and does not involve prejudging anything. The advantage of carrying out the climatological, the biological, and the policy implications in parallel, with uncertain values parameterized, rather than in series is the time-urgency of some of the possible implications for policy and doctrine. (As in electrical circuitry, the net resistance is larger when the resistors are in series than in parallel.) We agree that a study of the biological consequences of various Nuclear Winter outcomes could be important for biology even apart from the "practical" nuclear war implications. I suggest that something similar is true of a parameterized study on Nuclear Winter implications for policy and doctrine.

On the question of how to proceed with a parallel biological study, I would urge that a scientific drafting group be organized for the biological investigations somewhat similarly to the NOAA-led interagency drafting group for the climatological effects. There is, however, the difficult question of what is the appropriate organizing entity. The Department of Agriculture surely should be involved, but probably does not have the needed breadth of

expertise. This is probably also true for the National Institutes of Health, say, or the National Institute of Medicine. The American Institute of Biological Sciences and the Ecological Society of America bring very important skills, but are not even quasi-governmental organizations. The only solution that seems to me appropriate is for such a study to be a joint activity of the National Academy of Sciences and the National Institute of Medicine.

Cordially,

Carl Sagan

P.S. I hope to have a chance sometime to chat with you on a totally different matter -- a joint U.S./Soviet mission to Mars with a human crew as a major national objective, for some future time when the United States and the Soviet Union wish to demonstrate their ability to work together on behalf of the human species.

C.S.

CS/np

Nucl. Winter

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

August 20, 1984

NOTE FOR G. A. KEYWORTH

FROM: S. FRED SINGER

SUBJECT: NUCLEAR WINTER MEETING - ERICE, ITALY

On August 9, I attended SDI briefings held by a Republican Congressional Study Group. The witnesses were: General Abrahamson, Edward Teller, Robert Jastrow, Lowell Wood, and General Graham.

I spoke to Edward later about the forthcoming meeting on nuclear winter questions to be held in Italy. He had attended a similar meeting last year and urged me to accept their invitation. His Livermore people (Joe Knox, et al.) were going; so was Allan Hecht (NOAA).

But in the final analysis, I decided not to accept, pleading I was too busy. I would, if the invitation had come to me as an expert on the subject or in my academic capacity (rather than as a Consultant to OSTP).

S. FRED SINGER

1/31

Joey -

I'd like to brief you on the positive aspects of this Nuclear Weapons business ASAP.

PTO

Fred

Your Mic set up

Feb 9 at 10:15 am

Nucl. Winter

January 12, 1984

LETTER TO THE EDITOR

Science Magazine

Turco, Toon, Ackerman, Pollack and Sagan (TTAPS) in "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions" (1) attempt to deduce the detailed climatic events following a nuclear exchange. Their paper includes many important ideas, such as the atmospheric radiation consequences of smoke and soot from widespread conflagrations, but does not make it sufficiently clear that changes in the assumptions underlying their analysis can yield quite different climate consequences.

1. TTAPS predict a temperature drop to - 25°C over all land areas (except coastal regions), with subfreezing temperatures lasting some three months (the "nuclear winter"). The reason is that dust from the explosions, and especially smoke and soot particles from fires, keep sunlight

from reaching the earth's surface. But the particles could also keep heat radiation from escaping from the surface, thereby causing a "greenhouse effect" and heating (2). (The greenhouse effect would be enhanced by the large-scale injection of water vapor into the atmosphere, as a product of combustion and from vaporized moisture and water.)

The cooling or heating depends critically on the assumed sizes and optical properties of the particles. A change in these parameters affects not only the degree of the effect but even its sign. After all, the surface of Venus has a temperature of some 400°C and provides a convincing demonstration of a planetary greenhouse effect.

2. The duration of the nuclear winter is ascribed by TTAPS to the long atmospheric residence time of the particles. Indeed, volcanic eruptions have at times injected particles into the stable stratosphere where they survived for many seasons before falling out to the earth's surface. Three points could be made here:

(1) The assumed nuclear scenario is quite important. For example, nuclear bombs with yield less than 1 megaton would not project dust into the stratosphere. Several low-yield bombs are more destructive than an equivalent high-yield bomb, and may therefore be preferred by military planners. Also, air bursts cause wider destruction (and more fires and smoke) than ground bursts, but air bursts create less dust to project upward.

(2) It is not clear whether the conflagrations that follow the nuclear blasts and last perhaps several days would project much material into the stratosphere. This issue cannot be settled by a one-dimensional model but requires a mesoscale approach. The outcome is likely to be large-scale vertical convection with both upward and downward air currents. As with cumulus formation, there would be thunderstorms, rainout, and cleansing of the atmosphere.

(3) Finally, the stable stratosphere may be destroyed, thereby limiting the duration of the climate

effect. TTAPS point to destruction of ozone as a way of removing the temperature inversion at stratospheric heights, and thereby the stability. But convection reaching to these heights would destroy stability directly.

3. A separate issue is that monsoonal circulation driven by the large ocean-land temperature difference may greatly reduce severe climate effects on continents.

4. While the TTAPS results are presented in a properly qualified form, it is evident from the following paper (3) that their results are being uncritically accepted by many. That is not to say that the long-term consequences of a nuclear exchange should be discounted. Even with the TTAPS predictions reversed, a hot earth surface could be just as serious to the survival of animals and plants as a nuclear winter. But then again, the temperature change may be negligible and so would the biological consequences.

The same issue of Science (4) reports on a joint American-Soviet scientific forum, sponsored by the Nuclear

Freeze Foundation on December 8, 1983 (5) This forum sharply criticized a study prepared by the Federal Emergency Management Agency (FEMA), which suggests that food supplies would still be available after a nuclear attack. The FEMA study was faulted not only for its conclusions, which contradict those of (3), "but also for its underlying attitudes" (my emphasis). Senator Edward Kennedy was quoted as saying: "This kind of thinking makes nuclear war more likely because it makes nuclear war seem more bearable."

This remark raises ethical problems. First, does prediction of a global holocaust (3) make nuclear war less likely? And, second, should scientists therefore ignore scenarios which produce less severe global outcomes?

S. Fred Singer
Professor of Environmental Sciences
University of Viriginia
Charlottesville, VA 22903

Tel.: (804) 924-7761

REFERENCES & NOTES

1. R.P. Turco, et al., Science 222, pp. 1283-92, 23 Dec. 1983

2. A quite appropriate analogy is to consider the atmosphere as a leaky bucket. The inflow of solar energy (in the form of short-wave, visible radiation) must always equal the outflow of (long-wave, infrared) heat radiation, with the level of water in the bucket corresponding to temperature of the surface.

3. P.R. Ehrlich, et al., Science 222, pp. 1293-1300, 23 Dec. 1983.

4. J.L. Fox, Science 222, p. , 23 December 1983

5. Russian calculations apparently supporting those of TTAPS were reported at the Nuclear Freeze forum. (V.V. Aleksandrov and G.L. Stechikov J. Comp. Math Phys. 14, 140 - 144, 1983). But the authors used the same radiation specifications as TTAPS. Further, their global three-dimensional model cannot capture the mesoscale effects which may be determining the particulate content and optical thickness of the atmosphere and therefore its radiation properties.

6. The main points of this letter were presented by the writer at an informal session convened in connection with a symposium on global environmental problems held in November 1983 in Chicago, Ill. Some 20 participants attended the session and contributed discussion but did not necessarily endorse the conclusions.

SFS/11/25/83
11/30/83

NUCLEAR WINTER ON THE DAY AFTER?

S. Fred Singer

Who is right? The ABC-TV docudrama "The Day After" shows clear sunshine coupled with deadly radioactive fallout, while a scientific study by Prof. Carl Sagan and colleagues predicts a "nuclear winter" of darkness and cold. In an article in Parade Magazine, Sagan talks of dust, smoke and fallout spreading around the world following a major nuclear exchange, destroying agriculture and starving and freezing most of the human race.

It's difficult to make forecasts about global environmental effects. Item: If the earth is enveloped with dust, smoke, and especially soot, from the combustion of cities and forests, couldn't the surface become warmer rather than colder? True -- the sun's radiation won't reach the surface, but the heat radiation from the earth will be retained. It is precisely such a "greenhouse" mechanism that warms the surface of Venus to many hundreds of degrees -- as Sagan and colleagues well know.

Yet they chose Mars as an analog, where dust storms indeed have led to surface cooling. But Martian dust has different physical properties,and especially optical properties, than smoke and soot, or even terrestrial dust. And the other analog used, that is, terrestrial cooling after volcanic eruptions, may not be appropriate either, because such eruptions put aerosol droplets and dust into the stratosphere (where they remain for many months and even years), while smoke and soot from combustion following

nuclear explosions remain close to the surface. It may become dark and warm instead of dark and freezing.

Combustion of materials, and of trees and crops in rural areas, could certainly produce large quantities of smoke and soot. But rather than reflect sunlight back out into space (as Martian dust does), they would absorb solar radiation and create violent heating of the lower atmosphere. It is well known that this makes the atmosphere unstable, causes mixing and turbulence, cumulus-like cloud formation and intensive thunderstorms and rain. Such convective activity may promote rapid rain-out of whatever is contained in the lower atmosphere, speeding up the natural self-cleansing process. As a result, it may not be dark for very long.

But won't the dust kicked up into the stratosphere remain there? And won't chemical compounds , such as oxides of nitrogen created by the nuclear explosions, destroy the "ozone shield" in the stratosphere and thus allow "deadly solar ultraviolet radiation" to destroy living things on the land surface?

Here again, there are inconsistencies in the scientific scenarios prepared by Sagan and his colleagues. It should be obvious that ultraviolet radiation poses little danger to whatever survives at the surface. Since general solar radiation is screened by dust and smoke, so is solar ultraviolet. In fact, the explosions and subsequent conflagrations may create also a smog-like layer of low-altitude ozone which acts as a shield against UV. Not only that, stratospheric ozone would not remain destroyed; it reforms constantly and builds up towards its former value.

In any case, surface nuclear explosions are not nearly as effective in producing stratospheric changes as high-altitude bursts near the top of the atmosphere. But since such high-altitude bursts would not destroy cities, they are not likely to be employed in the conventional scenario of nuclear exchange. From the same military viewpoint, that is, to achieve maximum destruction at the earth's surface, many low-energy bombs would be more effective than fewer superbombs. The scientific reason is that a superbomb (with energy much above one megaton of TNT) wastes much of its explosive power by "blowing out" into the stratosphere and beyond. The atmosphere is simply not heavy enough to contain such a large explosion. Therefore a well-designed nuclear attack would use many smaller bombs and create little stratospheric impact; and by the same token, the aftereffects on solar screening, climate and fallout should be quite short-lived --measured in days rather than months or seasons.

The "nuclear winter" scenario may be internally inconsistent for a more fundamental scientific reason. If indeed the stratosphere is affected and its ozone destroyed, this would also destroy the temperature structure of the stratosphere itself and therefore its stability (which enables it to keep dust and aerosols suspended there for years). The (former) stratosphere would then become simply an upward extension of the troposphere (lower atmosphere) and participate in its instability, rapid mixing and clean-up by rain.

A case can therefore by made against a "nuclear winter" climate effect both from a scientific viewpoint and a military-strategic one. This argument is not meant to deny the horrible effects of a nuclear war -- the blast, high temperature fireball and the radioactive fallout -- although a modern hydrogen bomb is cleaner than an equivalent fission bomb of the type used in Hiroshima and Nagasaki. Rather, the purpose of my discussion is to illustrate the extreme difficulty of making predictions about what happens to the atmosphere after a nuclear exchange. Sagan's scenario may well be correct, but the range of uncertainty is so great that the prediction is not particularly useful.

Sagan's article is useful in other respects, however. It re-emphasizes the extreme danger to life on earth from large volcanic eruptions, and especially from the impact of meteorites or comets -- events which are at present outside of human control. The geological record suggests a number of instances where such occurrences did raise havoc, especially with advanced species. It is likely that the dinosaurs were wiped out by the climate effects following a meteorite impact 65 million years ago.

Perhaps without realizing it, Sagan has re-invented the "doomsday machine", first described many years ago by the late Herman Kahn. The doomsday machine is programmed to go off whenever it detects a nuclear attack; it then destroys the aggressor who set off the first bomb, and therefore acts as a deterrent to nuclear war.

But Sagan's "nuclear winter" does not work as a doomsday machine and may not be a deterrent. Even if both superpowers were to believe the climatic prediction and its dire consequences, it would not constrain a small nuclear power from launching bombs. On the contrary, it might feel more free to do so, believing that such actions on its part would not lead to a general nuclear exchange.

Professor S. Fred Singer, a geophysicist at the University of Virginia, has published extensively on global environmental issues. These views on the aftermath of a nuclear exchange were scrutinized by a panel of some twenty scientific experts at a recent symposium on global environmental problems.

Nuclear Winter

RESEARCH RELATED TO NUCLEAR WINTER

	PROBLEMS	RESEARCH
1)	Dynamics of Smoke Plume	
	o How do individual plumes coalesce?	Aerosol physics -- Dynamics of coagulation Mesoscale Mixing -- heating and horizontal defusion Insitu study of large fires -- Rapid Fire Response Program to measure particulates/unit fuel mass.
2)	Mesoscale Convection	
	o How do plumes spread vertically?	Mesoscale Modelling -- winds
	o What is effect of sun and day/night changes on cloud?	Radiation Cloud Aerosol Dynamics and modelling of temperature
3)	General Circulation	
	o How is cloud distributed globally and what is surface temperature?	Interactive GCM with aerosol transport and removal
4.	Atmospheric Pollution	
	o What are changes in ozone nitrate, sulfate and poisonous gases.	Atmospheric chemistry -- rates, types and impacts.

SFS/ 2/1/84

IS THE "NUCLEAR WINTER" REAL?

The paper by Covey, Schneider and Thompson (CST) (1) breaks new ground in atmospheric modeling. But does it really support the conclusions about a "nuclear winter" published by Turco et al (TTAPS) (2). In spite of the fact that CST usea global 3-dimensional model of considerable sophistication and have successfully adapted it to run under quite unusual conditions, they do not address in a satisfactory way the two crucial questions: (1) Will there really be a major cooling of the continental land masses (down to some - 40°C)? (2) And would any such cooling effect be maintained for months or seasons rather than days or weeks?

How Certain is the Cooling?

CST start their model calculations by assuming a particulate layer in place in the atmosphere as a result of conflagrations of cities and forests following a nuclear exchange. This layer of smoke and soot is assumed more or less uniformly distributed over altitudes of 1 to 10 km; thick enough (optical depth = 3.0) to cut off the (shortwave) solar radiation from the earth's surface but optically thin in the infrared (so that the surface can cool by radiating longwave radiation into space). In other words, CST accept the physical model of TTAPS and, not surprisingly, get a similar answer.

(i) The climate consequences depend on the detailed nuclear scenario, not just on the total megatonnage exploded (3). For example, air bursts will generate less nuclear dust (vaporized soil from the bomb crater) and radioactive fallout, but spread

the blast and heat radiation (which ignites the fires) over a larger area; while ground bursts produce more dust but less smoke and soot. Superbombs (greater than 1 megaton) will waste much of their power by "blowing out" into the stratosphere, since the atmosphere is not heavy enough to contain the explosion. Smaller bombs (less than 1 megaton) will be more destructive (per ton of TNT equivalent) but will not put dust into the stratosphere.

(ii) The temperature change of the land surface (assumed to have small heat capacity) depends on a temporary imbalance between two very small fluxes: The inflow of solar radiation and the outflow of infrared radiation, as well as the inflow and outflow of other energy fluxes. One cannot be sure even about the sign of the temperature change until all energy fluxes have been fully specified. TTAPS consider only a severe reduction of visible solar radiation and explicitly assume that the particle layer would be optically thin in the infrared, not affect IR transmission, and thus not create a "greenhouse" effect.

(iii) But the temperature change, its size and even its sign, depends crucially on the ratio of the optical thicknesses (visible: IR), and thus not only on the total amount but also on the size distribution of the particulates, and especially on their detailed optical properties.

The TTAPS paper does not make it sufficiently clear that the climate outcome depends crucially on the assumptions regarding the particles. The particle size distribution, in particular, is modified by agglomeration processes which are most important initially, when the smoke, soot, and ash clouds are quite dense.

For the same initial mass, the coalescence of particles into larger ones will increase the optical depth in the IR and decrease it in the visible.

(iv) Even if the particles were small enough to be transparent in the region of the atmospheric IR window (at around 8 to 12 microns), it is likely that the conflagration will generate a variety of complex gaseous combustion products with absorption bands throughout the infrared region.

(v) And even if particles or combustion gases do not produce at least a partial greenhouse effect, one cannot neglect water droplet clouds (located below the hypothetical particle layer), which would trap and re-emit IR radiation emanating from the land surface below.

About the generation of water vapor there can be no doubt, although this phenomenon was not considered in the TTAPS analysis. Combustion of dry mass must generate a corresponding mass of water vapor, since (CH_2) is oxidized to form H_2O. A total dry mass of 2.2×10^{13} kg (4) must lead to $\sim 2.5 \times 10^{13}$ kg of water vapor. The amount of water vaporized by the nuclear explosion itself is small: the energy of a 1-mt explosion ($\sim 4 \times 10^{15}$ joules), if converted at the rate of 1%, would lead to 1.6×10^{7} kg of H_2O. Quite important, however, is the conversion of the energy released in the combustion: $(2.2 \times 10^{13}$ kg of dry mass) $(14 \times 10^{6}$ joules/kg) $\sim 3 \times 10^{20}$ joules. A 25% conversion would generate another 2.5×10^{13} kg of H_2O.

If spread over the area of the fire, $\sim 10^{6}$ km^2, (4), the fire would produce from 2.5 to 5 g/cm^2 of water vapor (or from 2.5 to 5 cm at STP), and add substantially to the normal water

content of the atmosphere of about 2.5 g/cm^2. Such a large release of water vapor is entirely possible, depending on the state of the forest, the soil moisture, the existence of streams, etc. It is well known from experience with forest fires that steam is produced copiously, as well as clouds, making it difficult to spot such fires from IR detectors on weather satellites (5).

(vi) It follows from Kirchhoff's law that the particles, if poor IR absorbers, will also be poor IR emitters. This means that they would reach higher "temperatures" than a normal black body and and re-emit at wavelengths well below 10 microns, as well as conduct heat to the surrounding air. It would be important to calculate the amount of this radiation which is absorbed by the earth's surface and its effect on surface temperatures.

(vii) Another neglected heat source, warming the earth's surface, is the combustion energy of the very materials that contribute to the smoke and soot. The oxidation of wood releases 14×10^6 joules per kg; 1 kg per m^2 per day corresponds to nearly 200 watts per m^2 -- the average amount of solar energy at a cloudless low-latitude location. A smoldering combustion of only 1 ounce of material per ft^2 per day would generate about 50 watts per m^2, many times the minimum solar energy ($\sim 8 w/m^2$) calculated by TTAPS for their baseline case (2). This energy flux would be quite sufficient to keep the surface temperature from falling too low.

I conclude that surface temperatures are unlikely to fall very low; they could even increase -- if the particle size distribution, water clouds and combustion gases are such as to throttle the loss of heat radiation from the surface. Most likely, the temperatures will decrease by a few degrees (rather than tens of degrees).

How Long Would the Effect Last?

We now turn from radiation physics to atmospheric-dynamic considerations to discuss the lifetime of particulates in the atmosphere.

(i) It is clear that the 1-dimensional model used by TTAPS cannot capture mesoscale effects in the atmosphere. Nor, unfortunately, can the global 3-dimensional models of CST; their resolution is too coarse. Yet mesoscale effects are likely to determine the residence time of the smoke and soot particles. Experience with mesoscale models (6) argues strongly against the existence of a stable layer in the atmosphere where the solar energy is absorbed. To the contrary, one expects violent convective activity, even if the layer is initially uniform, leading to cumulus - type formation, thunderstorms, rain squalls and accelerated cleansing of the atmosphere.

(ii) Volcanoes do put dust into a stable stratosphere for many months but the analogy is not well taken. Tambora, which erupted in 1815, involved an energy release of ~ 8×10^{26} ergs (7), of the same order as the post-nuclear conflagration assumed by Crutzen and Birks (4), i.e. 3×10^{27} ergs.

But there the resemblance ends. Volcanic eruptions of acidic lavas can lead to explosions, while conflagrations evolve

hot gases slowly. Even the worst fire-storms during World War II lofted the smoke only to about 5 km (8). Furthermore, they were followed by intense rainstorms carrying showers of wet and sooty ash, suggesting that the fire-storm may have been responsible for the precipitation.

(iii) Further convective activity (plus rain showers and atmospheric cleansing) comes from the strong temperature gradient at the ocean - land boundary. Again, the 3-D model cannot capture these mesoscale effects, although the induced monsoonal circulation is yet another factor which limits large temperature excursions on the continents.

(iv) With the residence time limited by mesoscale effects, it is proper to question if there is enough time to disperse the particulates throughout the global atmosphere, as explicity assumed by TTAPS and CST. CST suggest that the radiative heating of the particles may affect the atmospheric circulation so as to speed up their dispersion. This may well be the case; although in the absence of a fully interactive, self-consistent calculation one cannot be sure how important the effect is.

Perhaps reasonably uniform dispersion can be achieved before rain-out cleanses the atmosphere, although in view of the foregoing this seems doubtful. More likely, one will see patchy clouds which thin out rapidly -- hardly a cataclysmic nuclear winter.

Conclusions

The papers published on "nuclear winter" and responses to them, open up an interesting scientific discussion which goes well beyond the question of the climatic effects following a nuclear exchange. One must be on guard in such scientific debates against introducing value judgments, such as: a less-than-cataclysmic forecast should be eschewed since "it makes nuclear war more likely because it makes nuclear war seem more bearable." Hopefully, the debate will stimulate atmospheric physicists, modelers, and climatologists, as well as planetary astronomers to develop the research tools suitable for tackling problems well beyond those that have been explored widely in the literature, including especially the climate effects of volcanic eruptions and asteroidal impacts.

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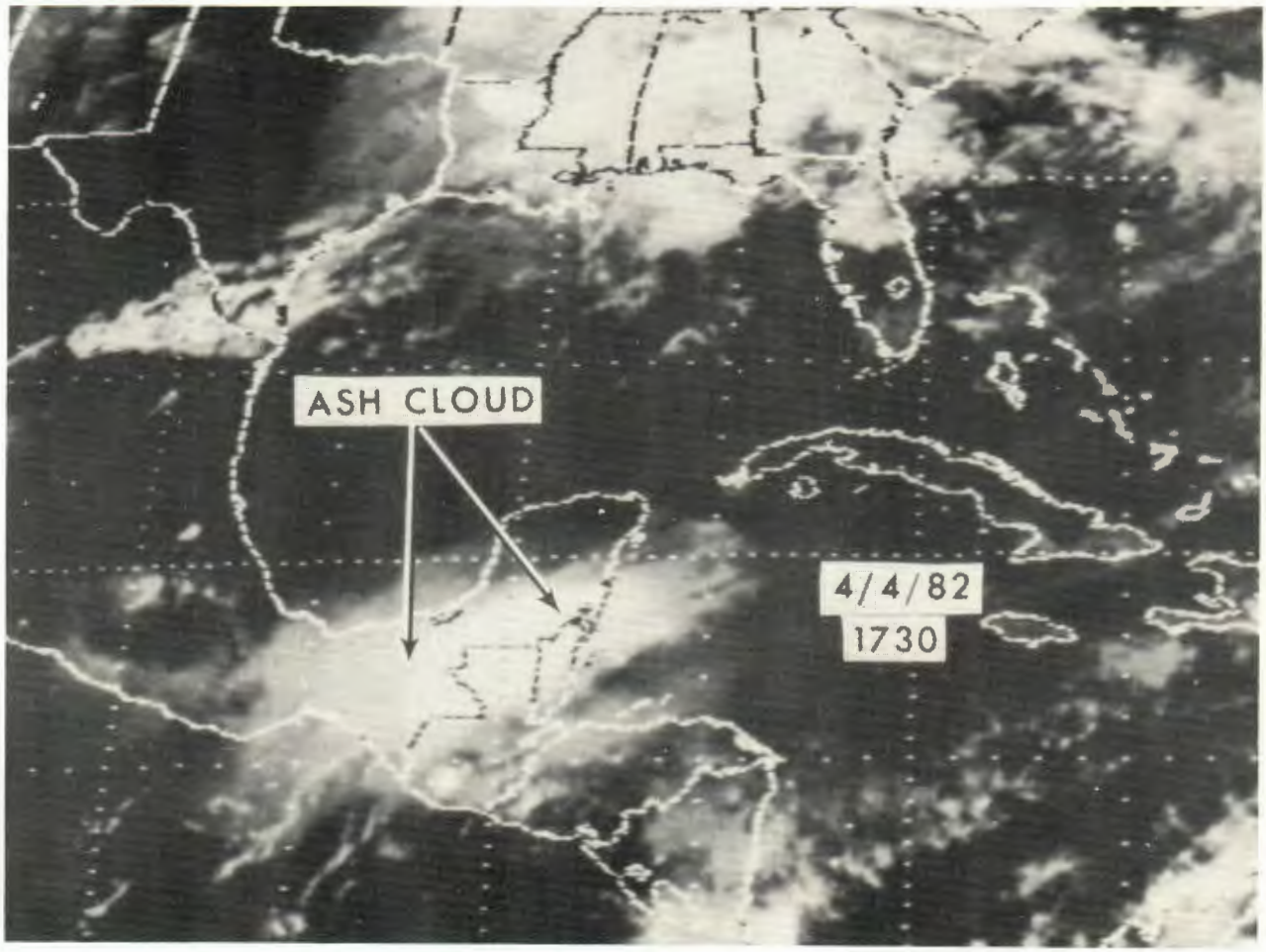
1982 Annual Report

National Climate Program



The cover photograph shows a thermal infrared image of the April 4, 1982, explosion of the El Chichon volcano in Mexico. The image was recorded by the Goes satellite at 1730 local time. Lower temperatures are lighter and higher temperatures darker. This eruption was primarily responsible for the stratospheric ash cloud that subsequently circled the earth. The westerly part is between 24 and 31 kilometers high (the stratosphere), while the easterly part is between 9.2 and 16.3 kilometers high (the troposphere.)

NATIONAL CLIMATE PROGRAM
ANNUAL REPORT
1982

PARTICIPATING AGENCIES:

Department of Agriculture
Department of Commerce
Department of Defense
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior
Department of Justice
Department of State
Department of Transportation
Department of the Treasury
Agency for International Development
Council on Environmental Qualtiy
Environmental Protection Agency
Federal Emergency Management Agency
National Aeronautics and Space Administration
National Science Foundation

Compiled by the National Climate Program Office
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
11400 Rockville Pike
Rockville, Maryland 20852
(301) 443–8981

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

OCT 12 1983

The President
President of the Senate
Speaker of the House of Representatives

Sirs:

I am pleased to submit the annual report on the activities of the National Climate Program, for fiscal year 1982, in compliance with Section 7 of the National Climate Program Act of 1978 (15 USC 2906).

Sincerely,

Malcolm Baldrige

Secretary of Commerce

Enclosure

ACRONYMS

ACRIM	Active Cavity Radiometer Irradiance Monitor
AGNET	Agricultural Network
AID	Agency for International Development
AISC	Assessment and Information Services Center
CAC	Climate Analysis Center
CAMS	Climate Anomaly Monitoring System
CDDB	Climate Diagnostics Data Base
CEAS	Center for Environmental Assessment Services (now part of AISC)
DOE	Department of Energy
EDIS	Environmental Data and Information Service (now part of NESDIS)
EPOCS	Equatorial Pacific Ocean Climate Studies
ERBE	Earth Radiation Budget Experiment
ESIC	Environmental Science and Information Center (now part of AISC)
FAO	Food and Agriculture Organization (UN)
GFDL	Geophysical Fluid Dynamics Laboratory
GISS	Goddard Institute for Space Studies
GLAS	Goddard Laboratory of Atmospheric Science
GOES	Geostationary Orbiting Environmental Satellite
ICDI	Interim Climate Data Inventory
ISCCP	International Satellite Cloud Climatology Project
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards
NCC	National Climatic Center (now NCDC)
NCDC	National Climatic Data Center
NCPO	National Climate Program Office
NEDRES	National Environmental Data Referral Service
NESDIS	National Environmental Satellite, Data, and Information Service
NESS	National Earth Satellite Service (now part of NESDIS)
NMC	National Meteorological Center
NODC	National Oceanographic Data Center
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OMB	Office of Management and Budget
PEQUOD	Pacific Equatorial Ocean Dynamics
SIO	Scripps Institution of Oceanography
SMM	Solar Maximum Mission
STACS	Subtropical Atlantic Climate Studies
TOGA	Interannual Variability of the Tropical Oceans and Global Atmosphere Project
TTO	Transient Tracers in Ocean
WMO	World Meteorological Organization
WAOB	Weather Agricultural Outlook Board
USDA	U.S. Department of Agriculture

PROGRAM HIGHLIGHTS

CONTENTS

OVERVIEW

Two events of the past year have demonstrated the importance of understanding climate changes and anticipating them—the eruption of the volcano El Chichon in Mexico and the warming of the sea surface in the equatorial Pacific known as the El Nino.

The only witnesses to the eruption of El Chichon in the spring of 1982 were the unfortunate villagers living near it, but it rapidly became one of the most intensely studied volcanic eruptions in this century. The amounts of ash and sulfur-containing gases it released at a high altitude are setting new records—NOAA's Mauna Loa Observatory in Hawaii recorded a density more than a hundred times greater than that released by Mount St. Helens.

Ash particles and sulfuric acid droplets have formed a stratospheric cloud which scatters sunlight and reduces the amount of solar heat reaching the earth. Because the El Chichon cloud is so huge and its absorption of sunlight may last for several years, there is reason to expect that it may cause changes in climate. A model simulation by NASA's Goddard Laboratory has estimated a yearly decrease in global average temperature of as much as 0.25°C beginning in 1984. Aircraft, balloons, and satellites are being used to collect information on the cloud and to track its progress.

Every few years sea surface temperatures in the equatorial eastern Pacific become warmer than normal. This warming extends from the coastline of Ecuador and Peru westward along the equator until it covers more than a quarter of the earth's circumference. The amount of warming varies from event to event.

Known as the El Nino, the ocean warming is an important element in a vast system of ocean-atmosphere climate fluctuations; in late 1982 and early 1983 the importance and vastness of this system became apparent. Sharp changes in the usual pattern of air pressure and flow between May and June were associated with large-scale changes in the rainfall regime in the Pacific. By September there was rapid warming in the eastern equatorial Pacific and the unusually high sea surface temperatures were associated with abnormal weather in large parts of the globe—in Ecuador and northern Peru the heaviest rain and worst flooding in 50 years; heavy rain in California, Louisiana, Florida, and Cuba; crippling drought in Southern Africa, Sri Lanka, Southern India, Indonesia, the Philippines, and Australia.

The loss in crops, property, and lives caused by these events has yet to be fully measured. As is typical during these events, the South American fisheries have been severely affected. Large numbers of sardines and anchovy have fled the warmer waters and those that remained suffered from loss of nutrients. Mackerel ate their own eggs, and near shore, shrimp fisheries showed the effects of an influx of fresh water. The migration of fish in search of food apparently also caused an entire population of sea birds to abandon nests on Christmas Island further along the equator.

The sheer scope and magnitude of the 1982-83 El Nino make it one of the more unusual and important of these climatic events in this century and the questions it has raised and the data it has provided will help to shape climate research for years to come.

The relationship between El Ninos and fluctuations in air pressure and flow known as the Southern Oscillation is being explored as part of a study of the equatorial Pacific Ocean. Briefly, the traditional hypothesis has been that the intermittent warming of the tropical Pacific leads to variations in atmospheric temperature and circulation. This idea is supported by model experiments which suggest that El Ninos can affect the monthly and seasonal atmospheric circulation over North America and cause significant climate anomalies. However, some recent studies appear to call this theory into question. More information is needed to learn about the way in which the air and sea interact.

The Transient Tracers in Ocean program was designed to study mixing of ocean waters and uptake of carbon dioxide by using man-made gases and radioactive isotopes. Experimental results are supporting model estimates that the oceans have taken up about 40 percent of the CO_2 produced by fossil fuels.

A recent sampling of North Atlantic deep waters shows that they are cooler and fresher than they were 10 years ago. These waters have cooled 0.15°C and decreased in salinity 0.02 parts per thousand. Laborador sea water is 0.05 parts per thousand fresher and 0.25° colder than it used to be. The exact cause of the change is unknown, but it could indicate that fresh water is being added by melting polar ice, brought on by climatic warming.

The amount of expected warming of the earth caused by accumulations of atmospheric carbon dioxide remains unclear. The data from observatories on Mauna Loa

and at the South Pole show that atmospheric CO_2 continues to increase yearly (up 1.2 parts per million in 1981) and that the increases have been closely correlated with greater use of fossil fuels over a 24-year period. A working consensus is emerging that it is too early to draw firm conclusions about the effect of increased atmospheric CO_2. Improved climate models, the use of more realistic climatic variables, and comparable model experiments are all needed.

A number of improvements have been made in providing climate information to the general public as well as users with specific needs. An inventory of historical climate data, the *Interim Climate Data Inventory*, has been installed on an information retrieval system that requires only a local telephone call to access and search the data.

An assessment of the severe 1981-82 winter was widely distributed and requested. Energy consumption models have been constructed to provide heating and cooling cost estimates for electric power, fuel oil, and natural gas and are regularly included in the *U.S. Energy Assessment* published by the Center for Environmental Assessment Services. The center has also expanded the geographic areas for which it prepares weekly economic assessments. It now evaluates 314 political/climate regions and expects to add another 51. In areas where data are limited and difficult to obtain, it estimates potential crop productivity by using historic climate data, information on impact of crop losses, and satellite-gathered precipitation data.

Detailed descriptions of seasonal climate variations, including U.S. temperature and precipitation patterns, tropical and Southern Hemisphere circulation, snow and ice anomalies, and sea surface temperatures are now being published in the *Monthly Weather Review*.

A computer-based system which will automatically monitor climate anomalies has been developed and will make it possible to detect and note in the *Weekly Climate Bulletin* regions where extreme climate changes can be expected. In addition, CAC data bases are now being used in special diagnostics bulletins on major fluctuations in the climate system. It is worth noting that the collapse of easterly winds during June and July of 1982 led the CAC to issue its first bulletin, which warned of the possibility of a major warm episode in the Pacific—the 1982-83 El Nino.

A variety of federal-state climate projects are under way or are being explored. In Nebraska, an automated weather network transmits data on wind, temperature, soil moisture, etc., to a computer-based system that is used for irrigation scheduling. In addition, a committee of agricultural commodity specialists reviews weekly weather and climate data and prepares advisory bulletins for the state. A regional climate coordinating center is being developed in Illinois to coordinate climate studies, advisory services, and data management for several states, and a regional climate office has been established at Cornell University.

A number of important national and international meetings are scheduled for the next year to further the development of programs to study cloud climatology, the interannual variability of tropical oceans and global atmosphere, and world ocean circulation, among others. The World Meteorological Organization Congress in May 1983 will approve activities of the World Climate Program for the 1982-86 period. Cooperative bilateral projects with the People's Republic of China, the Soviet Union, and France are also under way and will be expanded in 1983.

While most goals of the National Climate Program are being met, some important ancillary programs have had to be postponed. While the delays may not seem significant in themselves, they can affect the larger effort. The effect of budget restrictions is particularly noticeable in climate data management, an area important to the National Climate Program as well as the nation. All elements of the program depend strongly on the national data archives and these must be maintained at levels consistent with modern data management technology.

I. Introduction

The National Climate Program Act of 1978 (PL 95-367) established a program intended to assist the nation in understanding and responding to climate processes and their implications. Natural events as well as human activities affect climate in ways that may have profound social, economic, and political consequences. Thus, a program that allows us to anticipate changes in climate is vitally important to the nation's welfare.

Now in its fifth year, the National Climate Program is firmly established and has made considerable progress in meeting the goals mandated by the Act. The United States has a well-defined and coordinated program of domestic and international activities in research, monitoring, assessment, and utilization of climate information. In compliance with the Act, this annual report for 1982 describes the year's major activities, including a summary of achievements and an analysis of progress toward the objectives of the program. In addition, there is a summary of the FY 1982 to FY 1984 budget requests and recommendations for additional legislation to help achieve the goals of the Act.

The scientific and technical issues emphasized in this report are associated with the six principal thrusts originally outlined in the Five-Year Plan:

Activities	Thrusts	Lead Agency
I. Providing climate products	Generation and dissemination of climate information	NOAA
	Climate prediction and analysis	NOAA
II. Responding to impacts and policy implications of climate changes	Carbon dioxide, environment and society	DOE
	Climate and world food production	USDA
III. Understanding climate	Solar and earth radiation	NASA
	Ocean heat transport and storage	NSF

The grouping of the six principal thrusts within the three main activities has been altered in the report to give a clearer picture of the work being done.

Information on the activities described in this report was supplied by the agencies involved. The persons listed below can provide more details on specific areas.

Department of Agriculture (USDA)
Norton Strommen ..... (202) 447-9805
Department of Commerce (NOAA)
Rex J. Fleming ..... (301) 443-8415
Department of Defense (DOD)
Paul Try ..... (202) 695-9604
Department of Energy (DOE)
Frederick Koomanoff ..... (301) 353-3281
Department of Interior (DOI)
Richard Z. Poore ..... (703) 860-6411
Department of State (DOS)
William Long ..... (202) 632-2418
National Aeronautics and Space Administration (NASA)
Robert Schiffer ..... (202) 755-2420
National Science Foundation (NSF)
Thomas Crowley ..... (202) 357-9892

Overall information on the program may be obtained from the office of Alan D. Hecht, Director, National Climate Program Office, National Oceanic and Atmospheric Administration (301) 443-8646.

The current organization and staff of the NCPO are: administration and policy, Mason Charak and William Elliott; research and experimental forecasting, William Sprigg and Richard Newell; application and impact assessment, Howard Hill and Bernard Dethier; climate monitoring and data, Robert Etkins; and international activities, Martin Yerg; secretarial support is supplied by Wendy McGhee Graham and Brenda J. Shaw. This report was edited by Ruth B. Haas.

II. Summary of Significant Achievements in Principal Thrusts, FY 1982

PROVIDING CLIMATE PRODUCTS

HIGHLIGHTS

- Interim climate data inventory published
- New system for processing summary-of-day observations
- Ozone monitoring plan accepted
- Impact assessment of 1982 winter
- Climate and health programs initiated
- Long-term decrease in total solar irradiance
- El Chichon measurements

Generation and Dissemination of Climate Information

Climate information is generated and disseminated by federal, state, and local agencies; by universities; and by industrial meteorologists and private consultants. There was considerable progress this past year in improving the quality and quantity of basic atmospheric and ocean data bases, and in making them available to the general public.

A National Climate Data Inventory and Information Clearinghouse

The Environmental Data and Information Service (EDIS) has compiled and published the *Interim Climate Data Inventory* (ICDI), which has been installed on a nationally accessible on-line information retrieval system. The Environmental Science and Information Center (ESIC) demonstrated in a pilot operation that users with simple computer terminals can access and search the historical data inventory from hundreds of cities by using public data communication networks that require only a local telephone call.

As a first step toward establishing a climate data and information clearinghouse, ESIC began updating and expanding the climate data inventory as part of its National Environmental Data Referral Service (NEDRES) program. It is receiving records and data from several northeastern and north-central states, as well as Canada.

Upgrading Data Bases

The National Climatic Center (NCC) has developed new systems for processing over 8,000 summary-of-day (daily maximum and minimum temperature and 24-hour rainfall) and surface marine observations. More than 100 million observations have been converted to a new file structure and are now more readily accessible, with improved quality and reduced cost. A program to convert data to microfiche continues: 2.1 million pages were filmed and placed on microfiche in FY 1982. In the past two years, a total of 8.3 million pages of manuscript analog records and bibliographic data have been converted to 152,867 microfiche and added to this data base.

A return to processing hourly (vs. 3-hourly) observations from principal climatological stations has produced a year's worth of these historical data. These observations remain the number one priority data set in the NOAA climate plan for building the data base.

Over the past year, the National Oceanographic Data Center (NODC) added 19,500 expendable bathythermograph (XBT) observations (i.e., measures of temperature and pressure) to its data base. The Center significantly exceeded its planned level of making these data computer compatible. For the most part, information was drawn from the Southern Tropical and North Atlantic, North Pacific, Indian, and Arctic oceans.

The National Weather Service's Climate Analysis Center (CAC) continues to expand and increase the quality of the current or real-time data bases used for deriving climate-related assessments for the short term and for agriculture, energy, and water resource needs. The data processing system was changed to accommodate the new international code for meteorological surface data. The data bases have been expanded by adding hourly reports for the United States and information obtained from international stations through cooperation with the World Meteorological Organization (WMO); monthly global climate data reports have also been incorporated. One important result of these efforts has been the inclusion of more precipitation reports from stations in southeastern Asia, Indonesia, Australia, and the southwest Pacific Islands.

New software was also tested, revised, and implemented at CAC. It improves the ability to generate

and list diagnostic information, as well as to validate station data. Listings of validation information are being produced routinely for the six NWS regions, North America, most of the Caribbean, and eleven other countries.

The CAC began implementing a communication program for current data sets and products at the end of the year. The system is built around a microcomputer that can be dialed through the telephone system. Present requirements call for users to have an identification code and to absorb toll charges. A number of data sets are available for transfer and include weekly and monthly temperature and precipitation means and deviations from normal, and heating and cooling degree-days. Plans call for expanding the computer products to meet user needs.

Ozone Monitoring

The National Plan for Stratospheric Ozone Monitoring and Early Detection of Change was drawn up by the Federal Coordinator for Meteorological Services and Supporting Research and accepted by the agencies involved. It was published in February and is available from the Government Printing Office (Order No. 0-360-9971-204). This plan documents the requirements for a stratospheric monitoring program and the role of each agency.

Daily and monthly global operational analyses of total ozone derived from NOAA-7 data continued at CAC. Global monthly averaged total ozone and ozone mixing ratios at the highest levels of the atmosphere (30, 10, 5, 2, and 1 mb), derived from Nimbus-4 measurements (1970-76), were published as an atlas (available from NASA). Also, global, daily analyses of Nimbus-7-derived total ozone and ozone mixing ratios at similar altitudes for the first year of satellite operation (1978-79) were completed for the NASA archives. These two sets are being combined for comparisons with ground-based measurements to determine trends and ozone dynamics.

A method for determining distribution of lower stratospheric ozone was developed and described in a final report to the National Earth Satellite Service (NESS). In brief, dependent data sets from ozone soundings and Nimbus-4 radiation data (1970-71) yielded atmospheric parameters. Independent data sets verified that the retrieval technique is stable and yields profiles that are meteorologically and climatologically reasonable.

Data for Assessment: National

The special assessment, *U.S. Economic Impact of the Severe Winter of 1982*, is the latest in a series of reports that assess the effects of unusually intense or widespread meteorological anomalies. It was widely distributed and used on national television and in numerous newspaper articles. The report was heavily requested by governmental, business, and academic organizations. A main feature is a comparison of the total impacts and economic elements of major meteorological events: the 1976-77 and 1981-82 winters, and the 1980 heat wave. Such assessments can identify those sectors of the economy most affected by severe climate events.

Scientists in the Center for Environmental Assessment Services (CEAS) energy consumption program have constructed special models that provide heating and cooling cost estimates for electric power, fuel oil, and natural gas (figure 1). Population-weighted regional and national weather-induced energy costs are now regularly included in the CEAS *U.S. Energy Assessment*. The distribution of CEAS energy program products has been remarkably improved by weekly transmission of energy consumption charts over the national and digital facsimile circuits. There are plans to produce such charts for up to 30 days by utilizing the mid- and long-range forecast products of the National Weather Service.

EDIS, CAC, and USDA have improved a number of existing products and services, as well as developing new ones.

Heat wave index—weekly maps. The extensive heat wave over the United States in the summer of 1980 led the Community Services Administration to ask the National Weather Service for information that would help with decisions to distribute emergency aid. CAC produced heat wave index charts using temperature-humidity indexes and departures from normal temperatures. Since 1980, CAC has introduced into its operational files daily calculations of the temperature-humidity index (wind-chill in winter) for hundreds of U.S. cities. CAC will continue these calculations and plans to provide immediate access to these data via a dial-up communications system.

CAC/CEAS tables of degree-day parameters and outlooks. CAC has been producing heating and cooling degree-day parameters, tables, and analyses, and numerous customers already receive these products. The Center for Environmental Assessment Services (CEAS) uses CAC's heating and cooling degree-day products in its published assessments.

The publication, *Climatography of the United States, No. 81, Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1951-80* contains, for each state, the monthly and annual normals of temperature (maximum, minimum, and mean), degree days for 3,348 stations, and precipitation normals for 5,506 locations. The 1951-80 normals are the official reference point (baseline) for computation of monthly anomalies over the next decade and will be used to respond to customer requests for basic information on the climate of the United States. These and other periodic summaries are prepared by the National Climatic Center.

The Palmer drought and crop moisture indexes. The Palmer drought and crop moisture indexes are

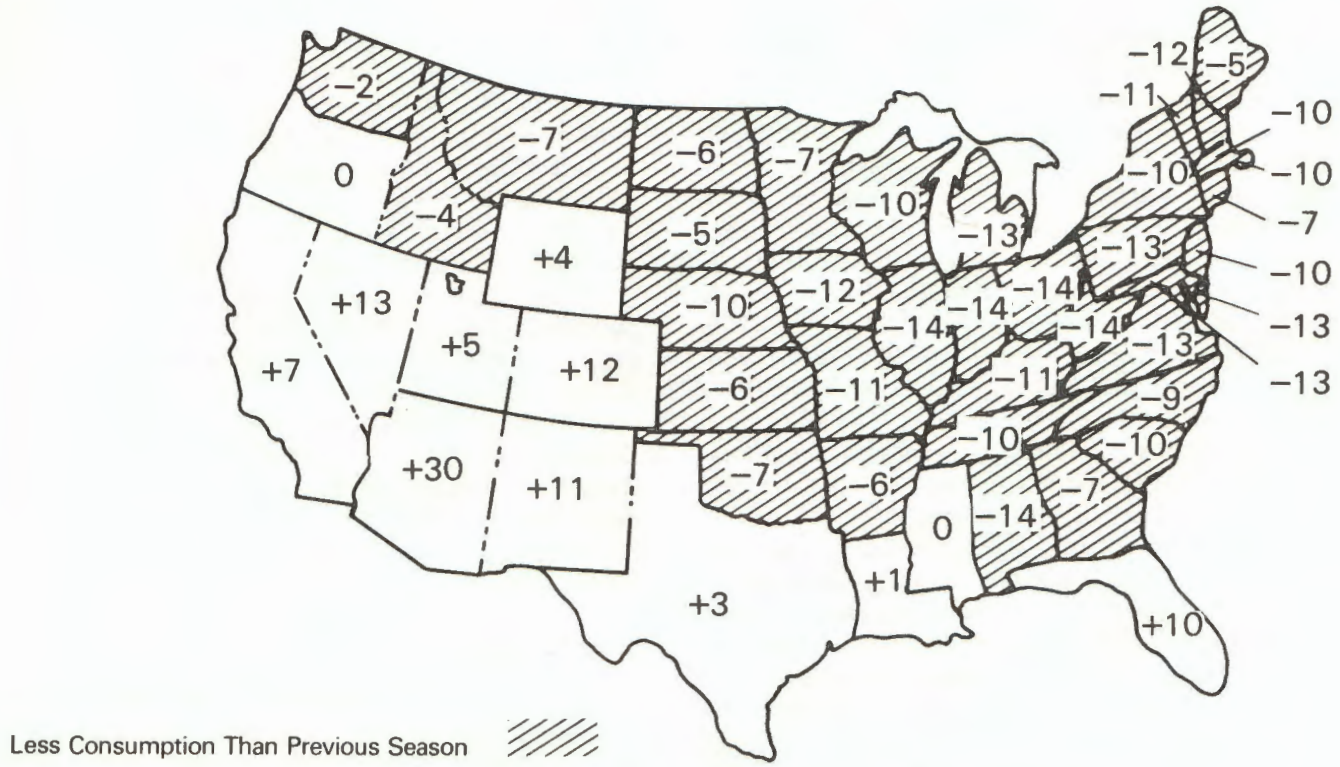


Figure 1.—State-by-state outlook of percentage change in yearly energy consumption using population-weighted degree days derived from estimates to date, 30-day and 90-day outlooks, and climatology.

good indicators of the relative wetness or dryness of soils. While the Palmer drought index indicates the prolonged and abnormal moisture deficiency or excess, the crop moisture index gives the short-term week-to-week change or current status of purely agricultural moisture surplus or deficiency. The two indexes are calculated for 350 climate divisions in the United States and Puerto Rico. Input includes current precipitation and temperature, information related to the particular division, and previous history of the indexes and soil conditions.

The Palmer drought index and the crop moisture index are published by CAC bimonthly and weekly, respectively, on a near real-time basis in the *Weekly Weather and Crop Bulletin* during the growing season. Use of the NWS automated field operations system (AFOS) for transmitting to NWS users these two indexes and the special input data used for calculating them is planned for 1983.

Assessment: International

The CEAS has greatly expanded the geographic areas for which it prepares weekly economic assessments. These results now evaluate 133 political/climate regions in Africa, 109 in South and Southeast Asia, 48 in South America, and 24 in the Caribbean Basin. In addition, 25 regions in Central America and 26 in Mexico will soon be added. The scope and content of the CEAS activities have also increased and CEAS has been asked for specialized assessments by particular groups within countries.

In areas where data are limited and difficult to obtain, agroclimatic techniques are used operationally to assess potential crop productivity. The system gives managers (FAO, AID, WMO, Food for Peace, etc.) a one-month lead time to plan ways to mitigate the impact of reduced crop productivity. The system uses historic climatic data, ancillary information on historic impact of crop losses, and precipitation estimates from satellite imagery. The effectiveness of the system can be largely attributed to continued close contact with users of the information.

Diagnosis of Recent Climate Fluctuations

During spring 1982, CAC began preparing a detailed description of seasonal climate variations for publication in the *Monthly Weather Review*. This new analysis replaces the long-running monthly "Weather and Circulation" series. These articles will describe the weather for each season and include charts and discussions of both seasonal and monthly mean Northern Hemisphere circulation, and U.S. temperature and precipitation patterns. Other aspects of global weather will be included, such as tropical and Southern Hemisphere circulation, snow and ice anomalies, sea surface temperature, and selected indexes of global climate fluctuation.

Climate and Human Health

The NCC is cooperating with a regional office of the Center for Disease Control (Memphis, Tennessee) in

examining the role that weather may play in mosquito reproduction and survival. A number of outbreaks of St. Louis encephalitis have occurred in Memphis since 1964 and mosquitoes are one of the prime vectors of the disease. Several meteorological elements (temperature, dew point, and precipitation) seem to be important in larval hatching. The Center for Disease Control will examine hourly data on these elements to learn more about their role in mosquito development and reproduction so that more effective methods of control can be devised.

The NCC is also providing climatic data to the Institute of Thermobaric Studies (Berkeley, California) for research related to sickle cell anemia. The Institute is investigating the possible climate/physiological relationship for this disease and will examine climatic data from regions where it is most common.

The development of a human activities index by CEAS is an important advance in understanding human sensitivity to the weather. This index provides a measure of the suitability of the weather (temperature, humidity, and wind speed) for human comfort and work. It is a more sophisticated, superior measure of ideal weather than either the temperature, humidity, or wind chill indexes. Assuming normal clothing for each locale, this index compares the impact of weather on comfort or human activity with the historical weather record for that location and time. Biweekly human activities indexes for 100 sites are being published in the CEAS *Climate Impact Assessment, United States.*

Solar and Earth Radiation

The storage and distribution of energy within the earth's climate system are manifestations of variations in radiation absorbed from the sun and emitted as heat from the earth. Consequently, monitoring these variations can provide important insights into climate changes. The major elements being monitored are solar irradiance, net radiation, radiation properties of land features, and aerosols and gases. Besides the geostationary and polar orbiting meteorological satellites, data to measure these elements are gathered by the Nimbus spacecraft, the Earth Radiation Budget Experiment satellites, and various aircraft, balloon, and U2 measurement systems.

Earth Radiation Budget Data

The first complete year of data from the Earth Radiation Budget (ERB) instrument on board the Nimbus-7 satellite is ready to be archived. Daily, 6-day, and monthly means of various radiation budget measurements are contained in the archive and an additional 8 months of data will be available by February 1983.

The mean reflected and emitted radiances for one day (10/14/79) have been compared in twelve target areas using data from Tiros-N, Nimbus-7, ERB, and Meteosat satellites in order to check for error. The results of this cooperative study between scientists at University College, London and NOAA/NESS show that there are deficiencies in the calculation of daily mean irradiances from the three satellites. However, because of the as yet small number of comparisons, it is not possible to make a formal estimate of the error in the systems, which would allow future measurements from one system to be compared with others.

Another study has compared radiation budget data from three different satellite systems and attempted to explain the physical reasons for the differences between the data sets and to estimate the size of the errors. This type of intercomparison with geosynchronous satellite data will be important for the NASA Earth Radiation Budget Experiment (ERBE), which will use simultaneous data from two polar orbiters and the ERB satellite to measure the radiation budget on a monthly averaged basis.

Solar Variability

The active cavity radiometer irradiance monitor (ACRIM) experiment on NASA's Solar Maximum Mission (SMM) has monitored the total solar irradiance on a nearly continuous daily basis since February 1980. ACRIM's current objective is to sustain the monitoring record until comparable new experiments can be deployed.

The cumulative record is shown in figure 2 as the percentage variation about a 1367.8 W/m^2 mean irradiance. Unfortunately, changes in the spin mode of the satellite have lowered data quality. The time scale over which solar irradiance changes ranges from seconds to the 2.5 year duration of the record. The results from the extended SMM record reinforce an earlier discovery that the largest irradiance variability, on time scales of days to weeks, is caused by the radiative deficit of sunspots and radiative excess of faculae in solar-active regions.

Evidence of many of the distinct irradiance variations found by ACRIM can be found in the Nimbus-7 ERB results, although some significant decreases are missing. Both records show the same general long-term trend of decreasing irradiance with time, but at different rates.

The results from the SMM are consistent with the findings of William Livingston (Kitt Peak Observatory), who has collected solar temperature data since 1975. A consensus has developed that variations in sunspot blocking of solar radiation do not significantly affect climate on time scales in excess of the 11-year sunspot cycle.

El Chichon

During late March and early April 1982, the Mexican volcano El Chichon ejected massive amounts of ash and sulfur-containing gases into the stratosphere.

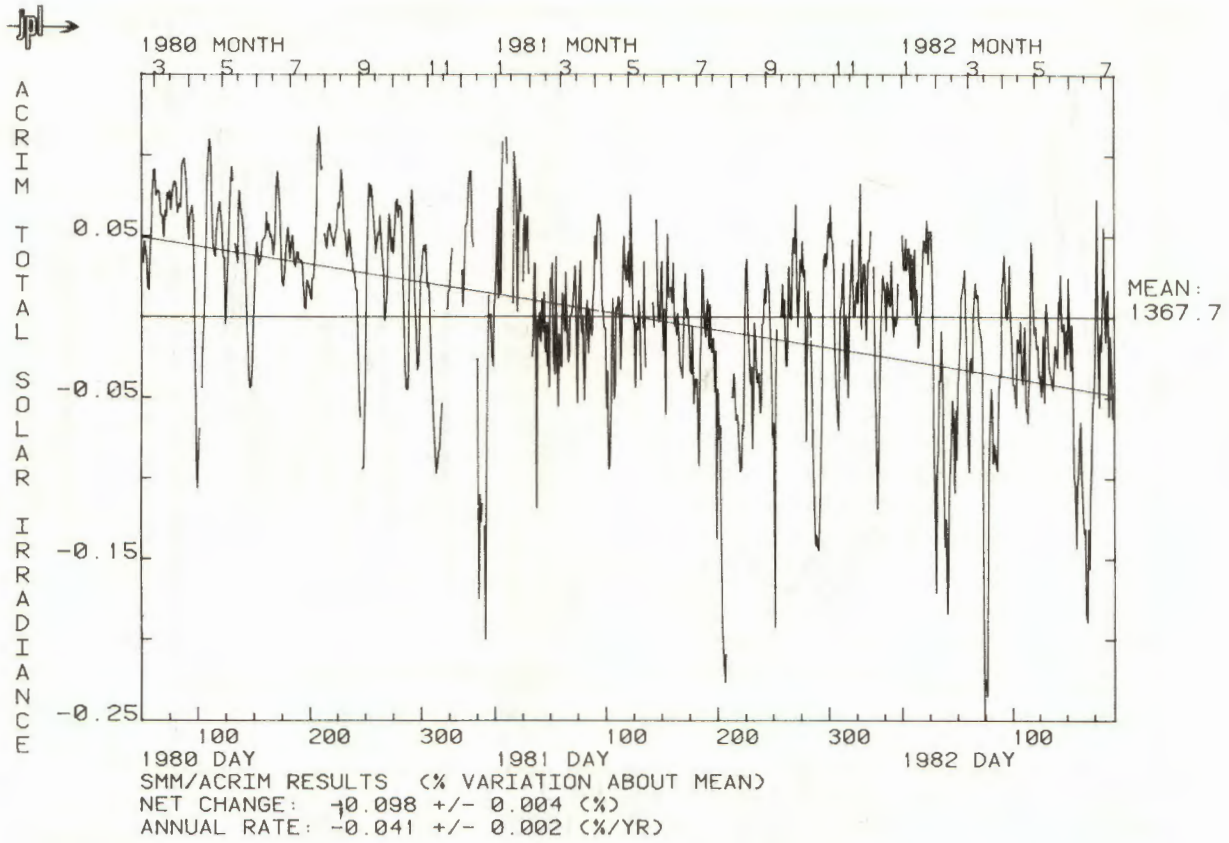


Figure 2.—Total solar irradiance derived from measurements from the Solar Maximum Mission experiment shown as a percentage variation about the mean for the mission. The long-term drift may be part of the changes in the solar activity cycle.

Throughout the first 6 months following these events, opaqueness caused by aerosols exceeded by more than an order of magnitude that caused by Mount St. Helens; it was comparable to the largest volcanic clouds of the past 100 years, such as Mt. Agung, Katmai, and Krakatoa.

Figure 3 shows aerosol data collected in recent years at NASA's Langley Research Center using the 48-inch lidar and indicates the estimated amount of ash and gases in the stratosphere that can be attributed to the volcanic eruptions listed along the bottom scale. During the period between the St. Augustine and Sierra Negra explosions, stratospheric aerosol was considered to be at a background level when no violent eruptions occurred. The measured values for El Chichon are record setting; most of the volcanically produced material is found above 22 km, with peak concentrations near 26 km, as shown in figure 4. This upper layer of material has generally spread from east to west and has predominantly been restricted to latitudes from 10°S to 30°N from April to October 1982. A lower cloud of much lesser aerosol mass, similar to that produced by the May 1980 eruptions of Mount St. Helens and other recent volcanos, has extended even farther, probably to the North Pole and possibly to high southern latitudes.

Because the El Chichon volcanic cloud is having a significant impact on the amount of radiation reaching the earth, because this impact might induce noticeable climate changes, and because it provides a natural geophysical experiment for testing climate models, NASA, with cooperation from NOAA, DOE, NSF, and various universities, is conducting a series of aircraft, balloon, and satellite measurements to determine the radiation properties of the cloud. These include U-2 aircraft to obtain in situ measurements and collect particles in the bottom part of the cloud; Convair 990 and Electra aircraft that fly beneath the cloud to measure its bulk radiative properties and vertical profiles by lidar; balloons operated by the University of Wyoming to obtain in situ vertical profiles; and special analysis of data from the Stratospheric Mesospheric Experiment satellite to map the distribution of the cloud from space.

Key results obtained from the aircraft and balloon platforms show that the volcanic particles are composed of sulfuric acid, silicates, and chlorine-containing compounds. During the first few months, many new particles of sulfuric acid were produced from the photochemical conversion of sulfur-containing gases; the particles were very efficient in scattering sunlight. Through the summer of 1982, the bulk of the high volcanic cloud was unable to move northward of 30°N latitude; the peak concentration was found at a height of approximately 25 km, with the volcanic cloud extending almost 10 km above and below this location (a second cloud is evident at about 18-20 km). Approxi-

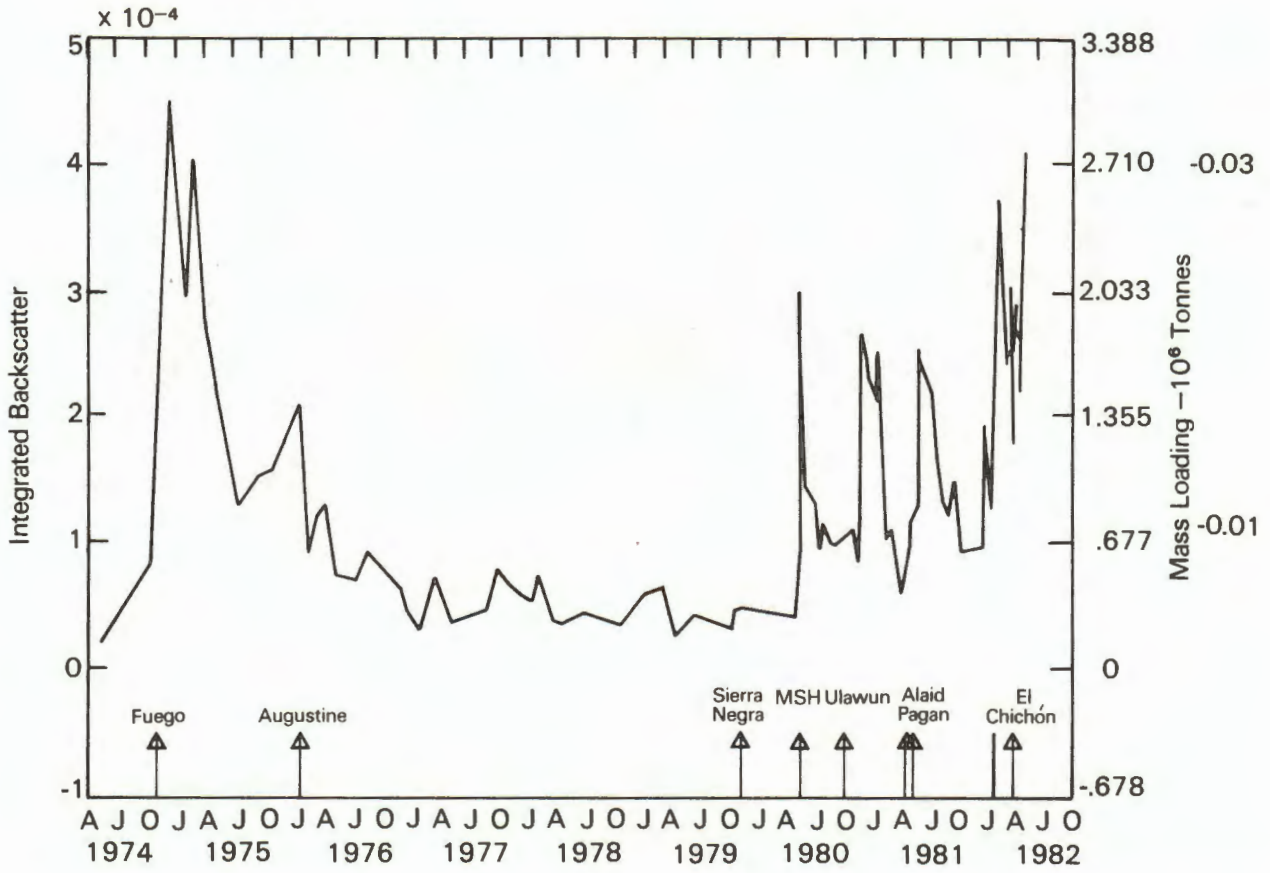


Figure 3.—The northern hemispheric integrated backscatter values give an indication of the amount of material (mass loading) placed into the stratosphere by the indicated volcanic eruptions. The period between Augustine and Sierra Negra is considered to be the background level. The maximum integrated backscatter value obtained on July 1, 1982, for El Chichon was 43 x 10^{-4} (off the scale of this figure).

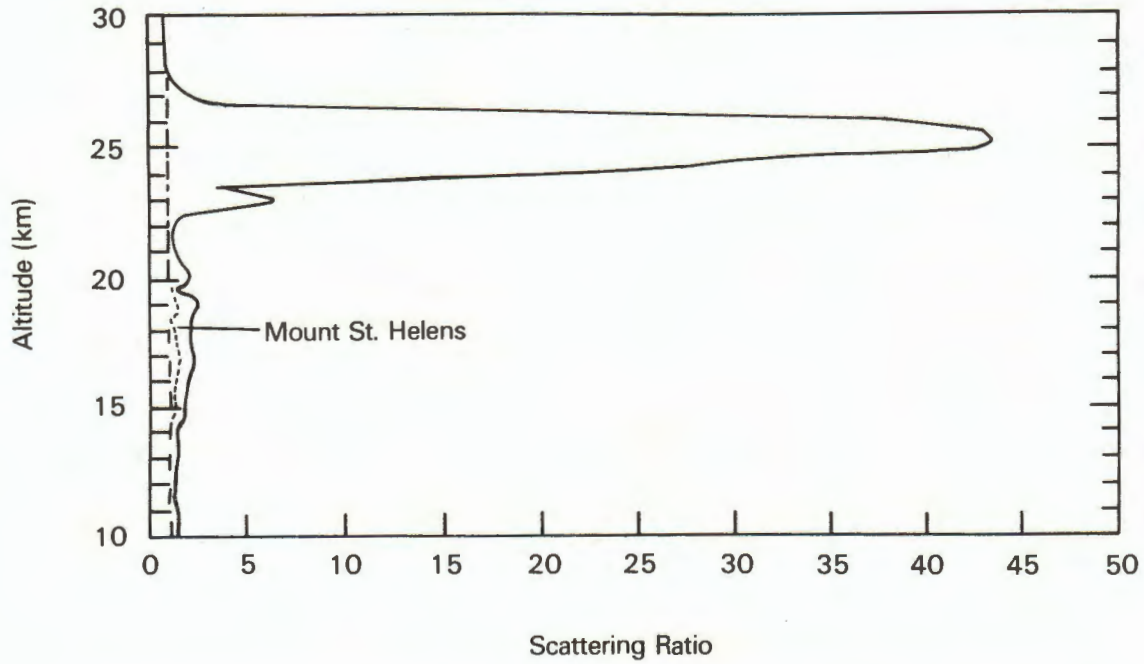


Figure 4.—Lidar measurements show the backscatter of light from materials in the stratosphere. The values of the scattering ratio show not only that El Chichon is record setting, but also that the peak concentrations are at about 26 km.

mately 5 percent of the direct solar beam in the northern tropics is being blocked by volcanic particles.

An effect of the El Chichon eruptions on satellite remote sensing capabilities has been evident in the interpretation of many meteorological and oceanographic quantities, such as sea surface temperatures and ozone. The remote sensing capabilities are affected by the quantity of aerosols, size of the particles, and the vertical distribution of the aerosol layer.

The very large increase in stratospheric aerosols induced by the eruption of El Chichon has led to widespread speculation concerning potential climatic effects over the next few years. The NASA Goddard Laboratory of Atmospheric Science's multilayer energy balance model has been used to simulate potential climatic effects based on currently available data on the optical thickness of the layer and its vertical and horizontal extent; expected changes in time (from observations of similar events in the past); and a range of particle sizes and composition based upon theoretical models.

Assuming that the volcanic aerosols spread from the equator to 30°N at a height of 27 km and there is an optical depth in the visible spectrum of 0.2 with a 2-year residence time, model experiments estimate the maximum effect on hemispheric and zonally averaged temperatures to be a decrease of about 0.25°C (see figures 5 and 6). Because of the thermal inertia of the ocean mixed layer, the peak response in the atmosphere occurs approximately 2.5 years after the aerosol layer has reached its maximum distribution. The low latitudes will cool first because the aerosol radiative effects are confined to those latitudes. Then the effects will cascade to higher latitudes, with the peak response delayed.

Clouds and Cloud Climatology

Clouds play a key role in the earth's radiation balance and, as one of the most variable components, are likely to be involved in important feedback mechanisms in the climate system. Thus they may strongly influence the ultimate effect of changes in other climate components, such as absorbed solar irradiance and composition of the atmosphere.

To learn more about how clouds affect the radiation balance, the Langley Research Center has derived regional and zonal cloud properties as well as surface radiative properties for a large portion of the western hemisphere for November 1978. This study utilized hourly, high-resolution, visible and infrared data from the geostationary operational satellite (Goes east). Quantities derived include the cloud amounts, infrared wavelength fluxes, and albedo (percentage reflection of incoming solar irradiation) at three levels in the atmosphere as well as the longwave flux and albedo over

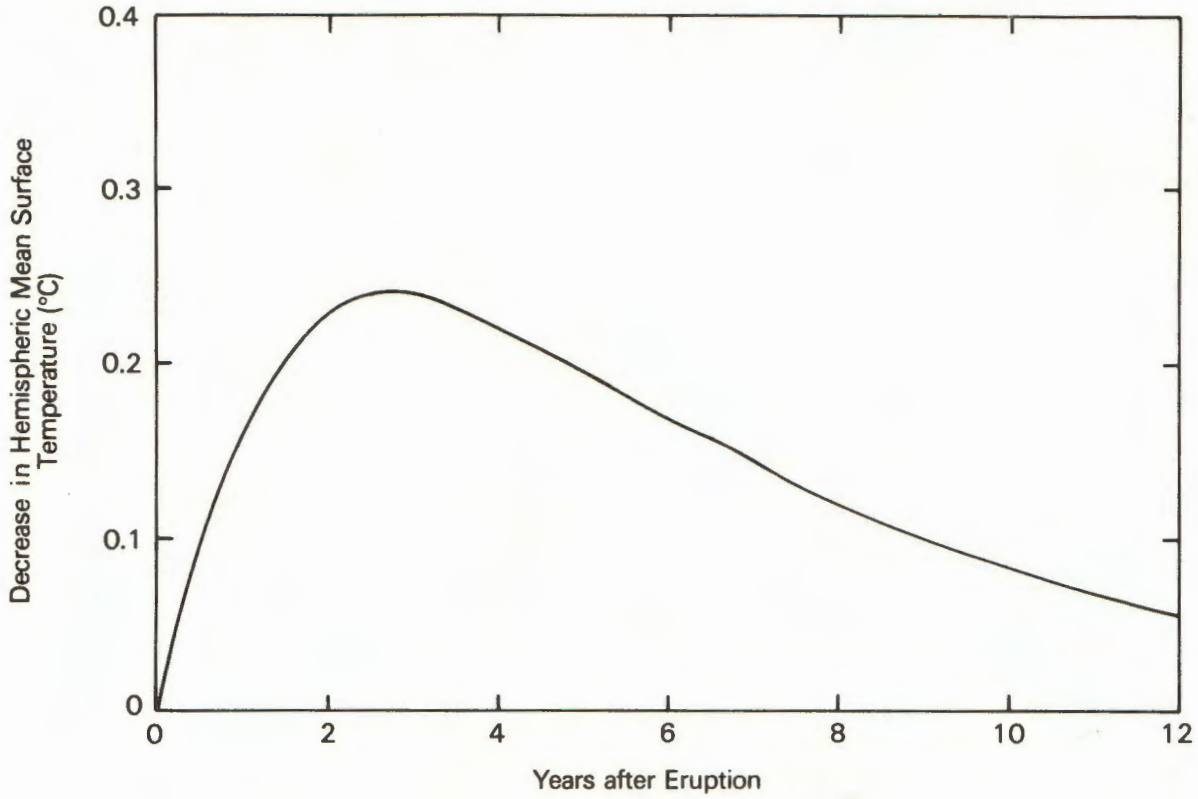


Figure 5.—The climatic effect of aerosols in the stratosphere on northern hemispheric mean surface temperature for 12 years is computed from a climate model which assumes that the height of the aerosols is 27 km, the extent of the aerosol cloud is 0 to 30°N, and that the optical depth in the visible wavelengths is 0.2 with a 2-year residence time.

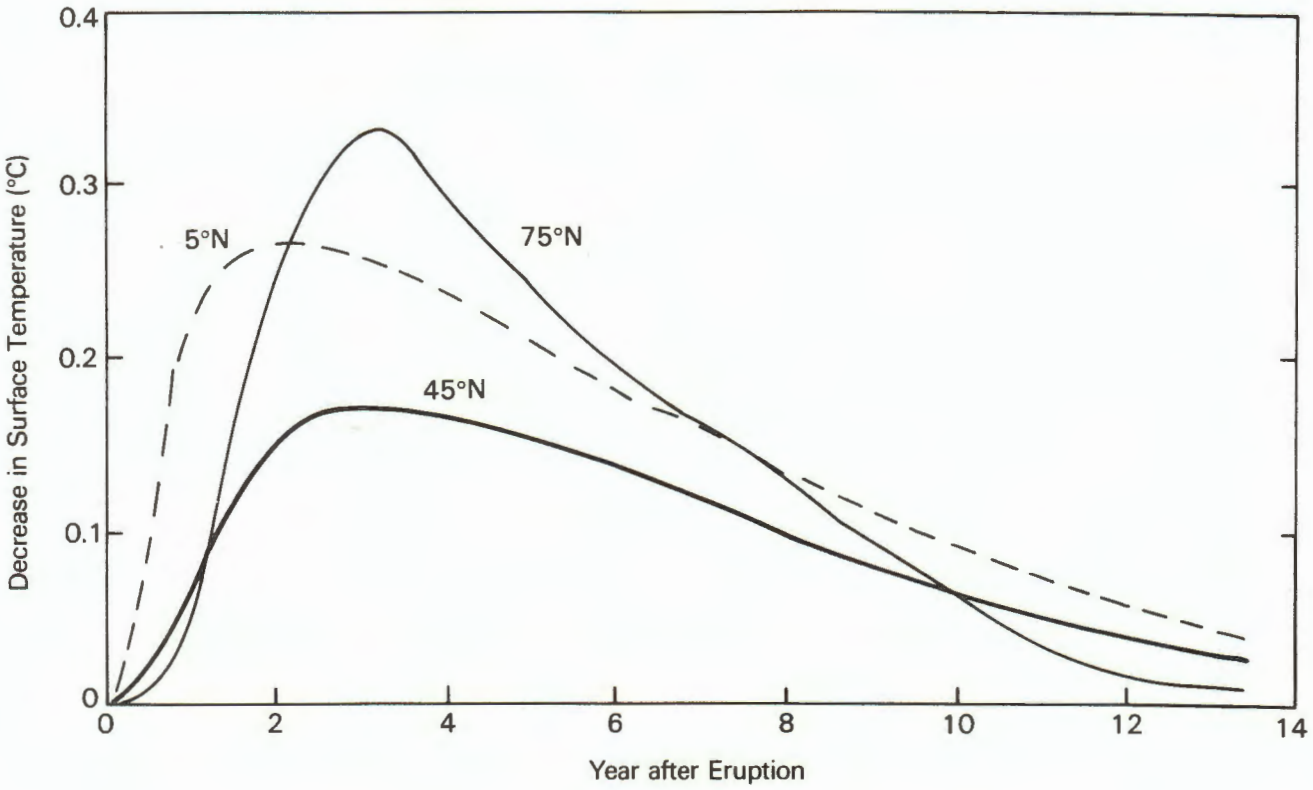


Figure 6.—The climatic effect of aerosols in the stratosphere on northern hemispheric surface temperatures for various latitudes is shown for 12 years using the same assumptions as for figure 5.

clear areas. A plot (figure 7) of clear-sky and total (clear and cloudy together) albedos shows the increase caused by cloud cover. For this particular data set, the solar radiation blocked by the clouds (cloud albedo effect) outweighs the infrared radiation trapped under and within the clouds (infrared effect) so that clouds caused a net cooling of the earth-atmosphere system. Goes data from other months are being analyzed to determine whether the net effect of the clouds remains constant or changes with time of year.

During the past year, NASA has supported programs to develop and test radiative transfer techniques to derive cloud properties from satellite measurements. A preliminary scheme, based on use of polar satellite observations, has been tested with data for the full months of January and July 1977. The data show a large seasonal variability, confirming the strong interrelations and feedbacks of clouds and climate. The complex geographical variations reaffirm the need for a uniform long-term global cloud climatology to assess cloud radiative feedbacks.

There are plans for an international program to assemble global cloud climatology for a five-year period. The current schedule calls for the International Satellite Cloud Climatology Project (ISCCP) to begin collecting global data on July 1, 1983 and continue through mid-1988. The first data on global cloudiness and radiances are expected in early 1984.

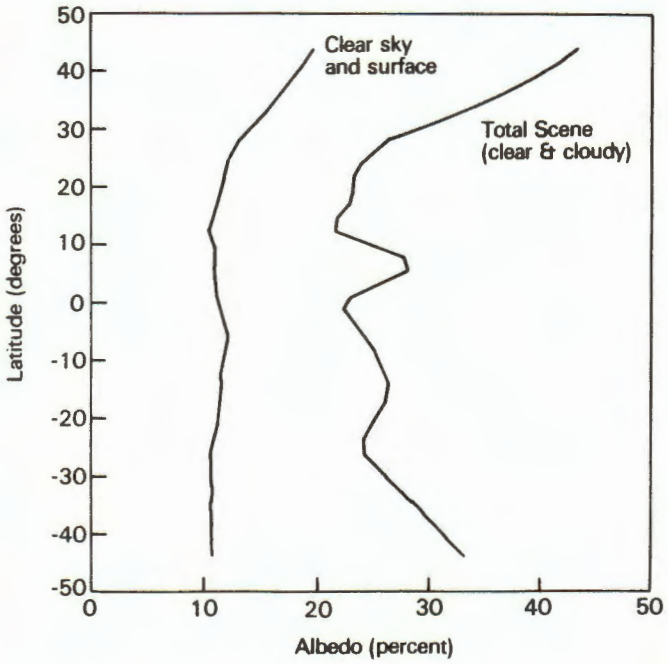


Figure 7.—Albedo measurements derived from Goes data for November 1978 (30°W to 120°W) show the increase in albedo due to cloud cover. The cloud albedo effect was found to outweigh the cloud infrared trapping effect, resulting in a net cooling in the earth-atmosphere system for November 1978.

CLIMATE RESEARCH AND PREDICTION

HIGHLIGHTS

- Evolution of a typical El Nino plotted
- Major warming of tropical Pacific sea surface temperature occurs
- Monitoring system for climate anomalies designed and developed
- Bulletins now available to document evolution of major fluctuations in climate system

Ocean Heat Transport and Storage

The ocean is able to store large amounts of heat more readily than the atmosphere. This heat can then be given back to the atmosphere at different times and places. This storage and transfer provide a slowly varying driving force for the atmosphere. Empirical data and modeling studies suggested that there are correlations, both simultaneously and with time lags, between changes in ocean temperature and atmospheric fluctuations.

The activities of this principal thrust have been of two types. The first consists of planning for national and international scientific programs. The second is a series of related ocean experiments. These are summarized below.

Equatorial Pacific Ocean Climate Studies (EPOCS)

The EPOCS program, sponsored by NOAA, is investigating the hypothesis that year-to-year changes in the equatorial sea surface temperatures are related to the cyclical fluctuations in air pressure and flows known as the Southern Oscillation. The essence of the El Nino/Southern Oscillation phenomena and the focus of the program are large-scale air-sea interactions.

The importance of this program became dramatically evident with the El Nino that began in late 1982. Warmer than usual sea surface temperatures caused severe changes in precipitation regimes across large portions of the globe which severely affected crops, property, and fisheries. It is too early to assess the effects of the flooding and droughts that resulted, but the economic and social costs will be high.[1]

However, the rapid exchange of meteorological, oceanographic, and fishing information that took place has provided data that are far superior to those obtained in the past. These are being analyzed and plans are under way for a major national research program into this complex system of climate fluctuations.

A picture of the evolution of a "typical" El Nino has been constructed by Rasmusson and Carpenter (1982) using composite fields for six earlier El Nino events. The results show that during a typical El Nino, unusually warm sea surface temperatures first appear off the coast of South America and then expand westward until the entire tropical Pacific Ocean is affected 6 months later (figure 8). The phase of the phenomenon in the eastern Pacific is the same as that of the seasonal cycle, so that the typical El Nino initially appears as an amplification of the seasonal cycle.

A study of rainfall over India reveals a strong tendency for the monsoon to average below the median value during El Nino episodes; this has occurred in 21 out of 25 cases. In the Southern Hemisphere, the midlatitude atmospheric circulation pattern in the Indian Ocean seems to affect westerly winds and unusual heat release in the western tropical Pacific. These teleconnections seem to be important on both interannual and decadal time scales.

Moorings containing current meters and thermistor chains have now been maintained on the equator near 110W for more than two years. The data show (1) the passage of an equatorial disturbance in the mixed layer of the ocean (Kelvin wave), which was also observed several thousand kilometers to the west; (2) very energetic oscillations, with a period of approximately 20 days, that are also seen in drifting buoy and satellite data; (3) a seasonal eastward acceleration of the surface flow and a simultaneous warming of the surface waters when the trade winds weaken during the spring. The observation of a Kelvin wave is particularly important because theoretical studies have shown that such waves should be one of the primary oceanic responses to changes in equatorial winds, and that they are possibly one of the major mechanisms responsible for the initiation of El Nino events because they increase the thickness of the ocean's upper mixed layer (the thermocline). When this happens, the colder, nutrient-rich water is no longer available.

The moorings, with hydrographic sections along 110W, have also established the spatial and temporal variability of the Equatorial Undercurrent, the North Equatorial Current, South Equatorial Current, and North Equatorial Countercurrent.

Subtropical Atlantic Climate Studies (STACS)

The general aims of STACS (sponsored by NOAA) are to identify those oceanic processes which contribute most to the poleward transport of heat and to develop the technology to monitor these processes. The major accomplishment in 1982 was the establishment of a monitoring grid to observe the heat and volume transport of the Florida Current. It is now possible to use Pegasus and current meters to observe directly the heat and volume transport of the Florida Current. This allows indirect techniques such as tide gauges, communications cables, codar (radar used to map ocean surface currents), and acoustic methods to be tested as tools for monitoring this current. As they are verified,

[1] A fuller discussion of this event, titled, "The Major Pacific Warm Episode of 1982-83," is available from the Climate Analysis Center, 5200 Auth Road, Camp Springs, Md. 20230.

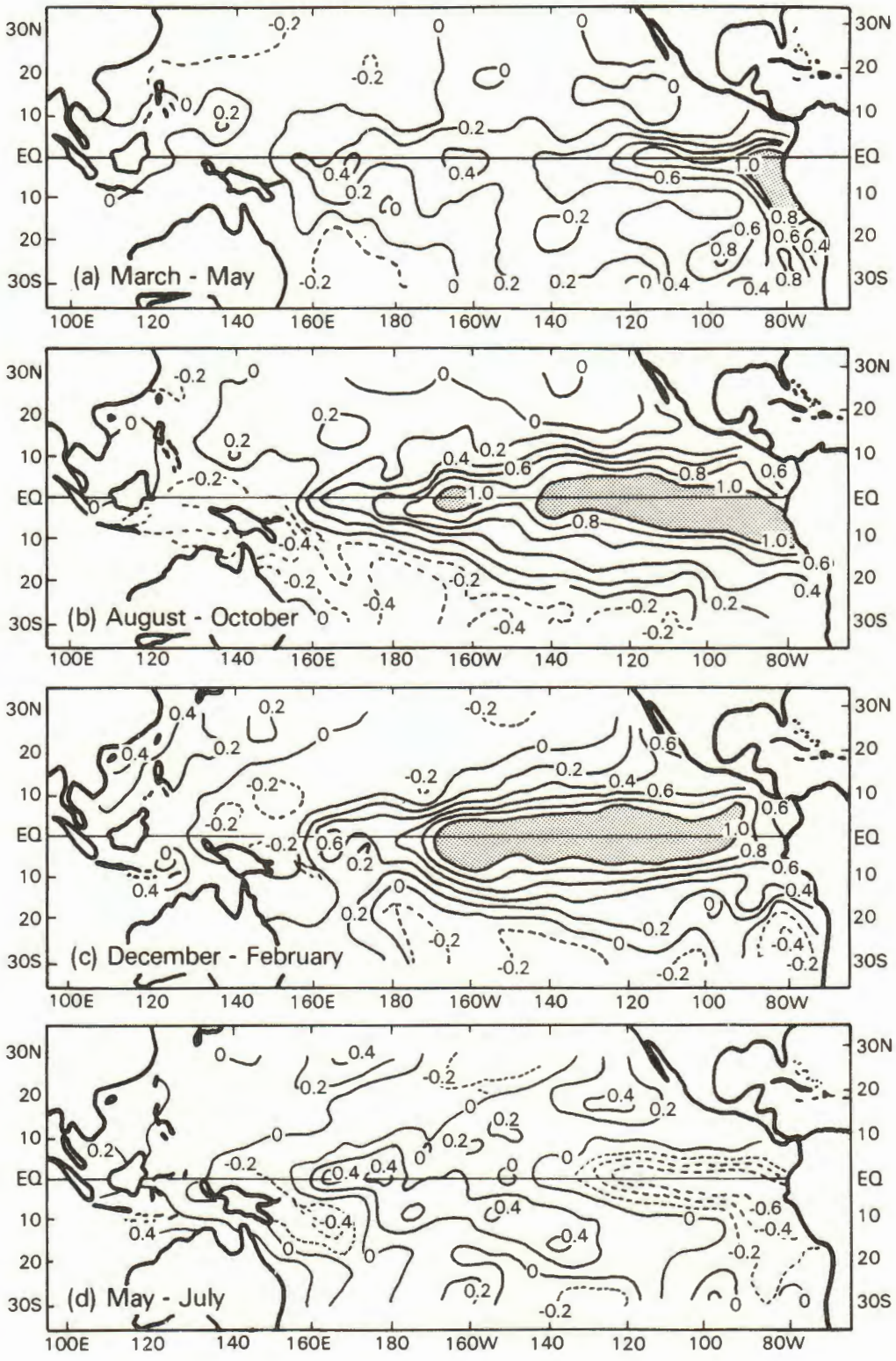


Figure 8.—A composite of the evolution of sea surface temperature anomalies over the equatorial Pacific during six El Nino events.

they will replace direct observations, saving both manpower and money. The goal is to monitor the heat and volume transport remotely and use the resulting time series in modeling and other monitoring efforts which consider the total oceanic heat flux in the North Atlantic.

Pacific Equatorial Ocean Dynamics (PEQUOD)

The primary objective of this project, which is sponsored by the National Science Foundation, is to understand the dynamics of the equatorial ocean. Field activities are focused in a region east of the Line Islands (160W). Measurements began in 1981 and will be completed in 1983.

Data collection has been successful so far and the efforts of the first field year are being processed and analyzed. Four cruises in the 148W-138W area have found significant variations in the transport of the undercurrent and a doubling of transport from January 1981 to April 1982. A comparison of measurements taken from the coast of South America with historical data indicates a deep warm pool of water in the eastern equatorial Pacific which might be a result of the previously strong transports of the undercurrent.

Ocean Monitoring Activities

Twenty thousand temperature profiles of the ocean were collected under the U.S. program in FY 82. These include continued collection of expendable bathythermograph (XBT) data in key areas of the equatorial and South Pacific. Operational sea surface temperature products are now made available every two days for any ocean/sea region in the world by the Marine Products Branch, National Meteorological Center. Both subsurface and surface temperature observations are used to help monitor and predict El Nino-related climate variations by the Climate Analysis Center. These data sets also contribute substantially to the PEQUOD and EPOCS ocean-climate research programs.

NOAA, the U.S. Navy, and Scripps Institution are continuing to develop and test several prototype systems for automatic digitizing and satellite relay of XBT data. This work is expected to lead to automatic ship-based observations and reporting of other oceanic and atmospheric variables as well, and to significantly improve data reliability. The U.S. continues to support the integrated global ocean station system (IGOSS) as an international mechanism for collecting and disseminating oceanic data.

Planning Activities

The Ocean Sciences Board of the National Academy of Sciences (now the Board on Ocean Science and Policy) is preparing a report entitled "Ocean Research for Understanding Climatic Variation—Priorities and Goals for the 1980's." It outlines research needs and puts them in an international context. Other NAS activities include scientific planning for studies of the El Nino/Southern Oscillation phenomena; a strategy for dealing with the components of a coordinated ocean-climate research program; and a study conference on large-scale oceanographic experiments in the World Climate Research Program. (A draft report of this conference is available from UNESCO, Paris.)

These activities have made it possible to identify the elements of national and international experiments, in particular, a world ocean circulation experiment (WOCE), a study of tropical oceans and the global atmosphere (TOGA), and pilot ocean monitoring studies (POMS).

Climate Prediction and Analysis

NOAA/NWS/Climate Analysis Center (CAC) introduced a new forecast format which gives the monthly and seasonal weather outlook in terms of probability contours. It also shows by stippling the most likely category of occurrence (see figure 9). By the use of three categories—warm, near normal, or cold temperatures and light, moderate, or heavy precipitation, the outlook is made to concentrate, as much as the state of the art allows, on significant departures from normal. A new forecast verification program has been devised to accompany this change in format.

The CAC has developed three new aids to prediction:

(1) Equations for specifying monthly surface temperature from upper air pressure patterns, (2) calculations that assess the significance of any relationship found between upper atmosphere pressure patterns over different time periods, and (3) equations that allow upper atmosphere pressure and surface temperatures to be predicted from Southern Oscillation indexes.

Improved empirical relations between anomalies of surface temperature and 700-mb circulation patterns that have been adopted by the CAC were obtained by using 33 years of monthly mean data over North America. These new relationships replace earlier data and are substantially better than persistence (repetition of present conditions) or climatology (mean values over a period of 30 years).

Experimental seasonal forecasts of temperature and precipitation are being made at the Experimental Climate Forecast Center/Scripps Institution of Oceanography for the contiguous United States using three different and independent procedures (synoptic, analog, and linear prediction). CAC and Scripps are assessing the operational value of these new methods. The Scripps center is also experimenting with two-season forecasting, the predictability of intraseasonal variability, and investigating objective methods to evaluate forecast skills.

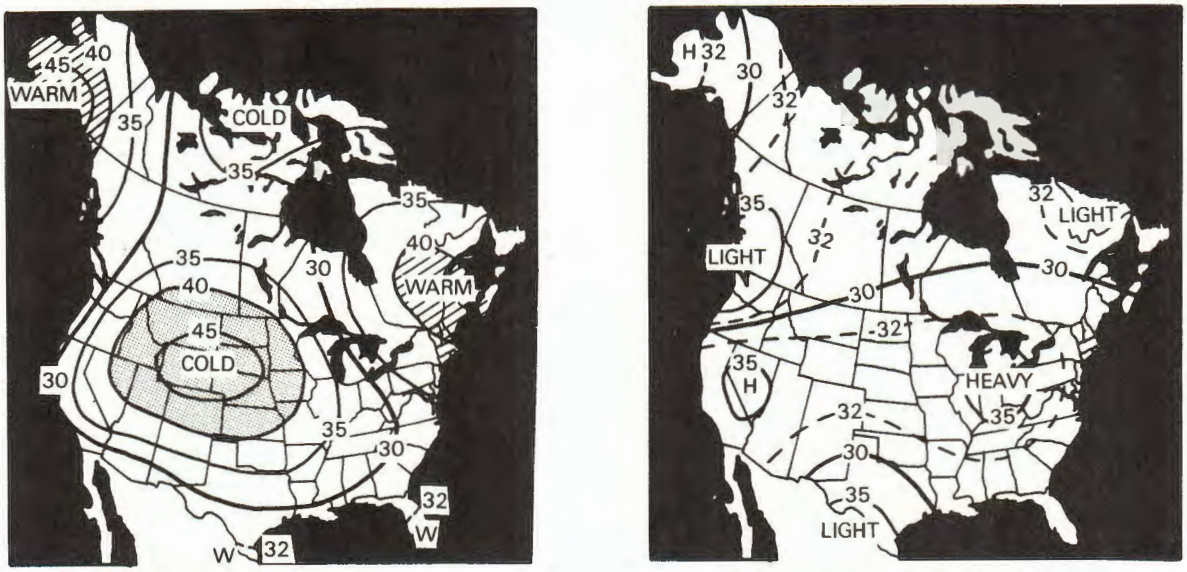


Figure 9.—The new probabilistic format initiated by the Climate Analysis Center, NOAA, for its monthly and seasonal outlooks (shown for October 1982). Predictions are given in three categories: warm, near normal, and cold for temperatures; light, moderate, heavy for precipitation. The near normal and moderate categories, being held at a climatologically constant 40 percent probability, do not show on the maps. Forecasts for Hawaii are also provided by the CAC but are not shown in this figure.

Monthly Prediction Using Dynamical-Numerical Models

The Geophysical Fluid Dynamics Laboratory (GFDL) is pioneering work in dynamic prediction using a general circulation model. Initial simulation of the 1976-77 winter over North America indicates promise in applying these models to prediction on a weekly time scale for certain atmospheric states. GFDL modelers are also working with new schemes for incorporating clouds in climate models and in developing general circulation models for the ocean.

Recent studies indicate that the equatorial Pacific sea surface temperature (SST) anomalies referred to as El Nino events can produce significant climate changes over North America. A numerical experiment by Shukla and Wallace (1983, in press) used the GLAS climate model to test the validity of this hypothesis. The January initial condition was based on observed data and the equatorial Pacific sea surface temperature anomaly was based on the recent analysis of Rasmusson and Carpenter (1982). Figure 10 shows the difference between the anomaly and control simulations averaged for days 11-30 for upper atmosphere pressure patterns. Positive and negative values of height differences indicate areas of warmer and colder air temperatures respectively. The maximum changes occur over North America. These results confirm earlier suggestions for upper tropospheric patterns that were based on observation and simple model studies, and highlight the importance of equatorial Pacific ocean temperature anomalies in the monthly and seasonal mean atmospheric circulation over North America.

Climate Diagnostics Studies

A great many diagnostic studies related to the Southern Oscillation and El Nino phenomena are now under way. It is apparent that these phenomena, although observed in the tropics, are connected to events in tropical and extratropical regions in the northern and

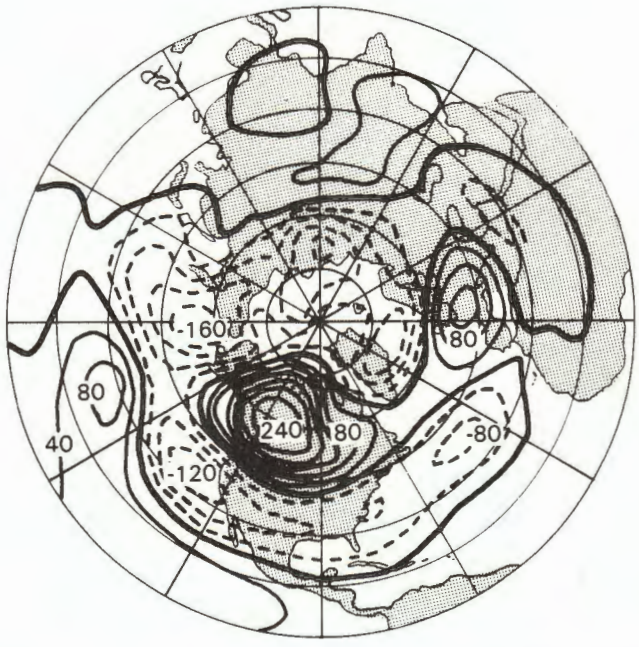


Figure 10.—The results of a numerical experiment by Shukla and Wallace using the GLAS climate model to test the hypothesis that sea surface temperature anomalies similar to those of a typical El Nino event can produce significant anomalies in the upper atmosphere over North America. Positive (negative) values indicate warmer (colder) tropospheric temperatures.

southern hemispheres. These studies complement the coherent picture of the evolution of the last six El Ninos in the Pacific described in an earlier section.

In addition to the Southern Oscillation-related studies, the following diagnostic studies were also sponsored by the Climate Analysis Center as part of EPOCS.

Variations in zonal mean sea surface temperature (SST) and large-scale air-sea interactions are being investigated. Based on 24 years of data, it was found that outside the tropics, annual and semiannual fluctuations of SST accounted for over 90 percent of the total temperature variance. A statistical analysis showed that the major global pattern of zonal mean SST variations is dominated by the equatorial eastern Pacific and that these variations precede changes elsewhere. The statistical time series correlates with an index of the Southern Oscillation. An examination of the relationship between SST and tropical tropospheric temperature showed that in the Atlantic and Indian oceans these variations are almost contemporaneous.

Diagnostic studies of Pacific sea surface temperatures and Pacific surface winds were made from a 100-year data set in order to study the time evolution of the Southern Oscillation. Results showed that there is higher cyclonic vorticity in the subtropics (the western Pacific) 6-12 months before eastern equatorial Pacific sea surface temperatures change.

The interannual variability of climate and atmospheric circulation in the Atlantic and Indian ocean sectors of the tropics is being studied empirically, with emphasis on the mechanisms of regional climate anomalies and large-scale linkages. Earlier work indicates that long-term large-scale mass redistributions are responsible for the major circulation and climatic anomalies in much of the global tropics. Hence, the processes that produce mass gain and loss in the atmospheric column over the "centers of action" are being studied with the aim of fitting major mechanisms of interannual variability into the larger picture.

Some aspects of the variability of the atmospheric general circulation in the Southern Hemisphere are being studied, with emphasis on the 500-mb level. Interannual variations are pronounced and show a quasi-biennial fluctuation in the mean fields, with a systematic progression of anomalies from low to high latitudes. This pattern is strongest and most consistent in the Australia-New Zealand region and may provide a basis for making 3-6 month circulation and weather forecasts.

A data-based analysis of the role of snow cover in short-term (weekly to seasonal) climatic variability by Walsh et al. (1982) showed that snow cover over much of the United States correlates almost as highly with North Pacific 700-mb as with local 700-mb heights. The results suggest that the potential predictive value of snow cover in the United States is greatest during the latter part of the winter and in the midwestern states.

Additional climate diagnostic studies conducted by CAC included:

A joint study with NESS focused on variations of Northern Hemisphere snow cover patterns in transition zones between maximum and minimum snow cover. Preliminary findings show negative correlations between snow cover in western Europe and central Asia.

A precipitation index is now being routinely computed to estimate area-averaged precipitation for areas viewed by U.S. Goes. Comparisons between index values and current monthly rainfall data for stations in Central and South America and islands in the eastern Pacific and western Atlantic show good agreement.

An examination of seasonal variances of satellite-derived outgoing longwave radiation for the summer 1974 through the summer 1982, along with 200-mb eddy statistics, has shown that when westerly winds over the eastern equatorial Pacific are strong, a region of high variability extends southward toward the Equator from the North Pacific jetstream just east of the dateline.

A fuller discussion of U.S. work in climate diagnostics can be found in the proceedings of the 6th Annual Climate Diagnostics Workshop held in cooperation with the Lamont-Doherty Geological Observatory/ Columbia University in October 1981.

Climate Monitoring

A comprehensive plan for a climate anomaly monitoring system (CAMS) was designed and developed at CAC/NOAA. The CAMS is a computer-based system that will automatically flag significant departures from normal and will provide a mechanism for systematically monitoring accumulated departures, isolating regions of extreme climate events. It should supplement and extend the information now provided in CAC's *Weekly Climate Bulletin* and will be used extensively for climate statements.

The climate diagnostics data base (CDDB) became operational in FY 82. It contains a comprehensive global general circulation data file (based on NMC model analysis), snow cover, ice cover, radiation, and sea surface temperature (and mixed layer) data as well as selected climatologically important indexes. The CDDB is the basic data source for CAC's seasonal climate review and is used in climate monitoring and research.

A procedure was developed for preparing special climate diagnostics bulletins, based on information in the CDDB, which will comprehensively document the evolution of major fluctuations in the climate system. These bulletins will be of interest principally to the meteorological and oceanographic research, academic, and government communities.

The first CAC special climate diagnostics bulletin was prepared and distributed in September 1982 and described anomalous conditions that developed in the eastern equatorial Pacific in June. Fluctuations in sea

surface temperature and the collapse of easterly winds during June and July indicated that there was a possibility of a major warming of equatorial Pacific temperatures. Further bulletins documented the development of the event. By December, the SST over large areas of the eastern equatorial Pacific were 4°C warmer than normal and some local areas were as much as 6° warmer. The 1982-83 Southern Oscillation-El Nino, drastically altered normal precipitation patterns and produced floods and heavy rain in Ecuador, northern Peru, California, Louisiana and Cuba and severe drought in Southern Africa, Sri Lanka, Southern India, Indonesia, the Philippines and Australia.

CLIMATE IMPACT AND POLICY

HIGHLIGHTS

- CO_2 emissions continue to increase
- TTO program shows decrease in North Atlantic salinity
- Irrigation and weather data network expanded

Carbon Dioxide, Environment, and Society

Interpretations of Atmospheric CO_2 Data

There are now over 20 years of precise data on atmospheric CO_2 from observations at Mauna Loa and the South Pole, and additional data from shorter term stations. These data continue to show a yearly increase of atmospheric CO_2 (0.8 ppm/yr growing to about 1.2 ppm/yr in 1981), which is closely correlated with an increasing growth rate in use of fossil fuels. This suggests that unless other factors, such as deforestation, result in a CO_2 increase that grows at the same rate as that attributed to fossil fuels, the nonfossil fuel sources are likely to be small.

An analysis of the long Mauna Loa record shows that the annual amplitude of CO_2 seasonal variations is increasing slowly (figure 11). One explanation attributes this to increasing biological activity in the temperate and high latitude Northern Hemisphere, i.e., the cycle of summertime photosynthetic CO_2 uptake and oxidation of organic materials in winter.

The north-south profile of CO_2 from ground-level U.S.-operated stations reveals a maximum CO_2 concentration in the north temperate latitudes. This is attributed to heavier use of fossil fuels in these latitudes. A secondary, much smaller peak appears in the equatorial region; presumably it is caused by CO_2 emitted from the equatorial upwelling oceans. The tropical peak may also be due to the loss of tropical forests, which take up CO_2. While it is not yet possible to explain the exact source of the observed equatorial CO_2, stable isotope data suggest only a weak terrestrial source. There is a third, even smaller, peak in the latitudinal profile at the edge of Antarctica, which may be caused by upwelling ocean currents that release CO_2 to the air. Based only on interpretations of atmospheric CO_2 data, the amount of CO_2 added because of deforestation is believed to be a fraction of that released by fossil fuel combustion, probably no more than 20 percent of the fossil fuel emissions.

Carbon Dioxide Standard Reference Gas

An essential ingredient of the atmospheric CO_2 measurement program is a standard reference gas that can be used for calibrating instruments and comparing data obtained from the laboratories of different countries. In 1980, a CO_2 standard reference gas was prepared by the National Bureau of Standards (NBS), and its CO_2 content determined by NBS (gravimetrically) and the Scripps Institution of Oceanography (SIO) (manometrically). In 1982, three NBS standard

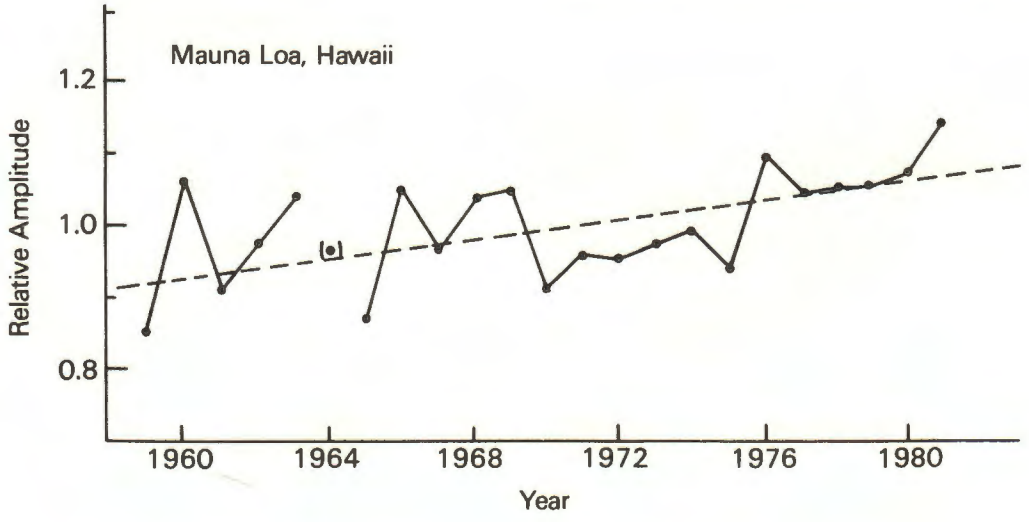


Figure 11.—The annual range of the seasonal variations of CO_2 since 1959 as measured at Mauna Loa, Hawaii. (From C.D. Keeling, Scripps Institution of Oceanography.)

reference materials (SRM numbers 1670, 1671, 1672) for CO_2 in air were certified for CO_2 content and a subset compared with SIO CO_2 standards. The results (average difference +0.01 ppm) indicated that agreement is within the accuracy of the respective methods. There appear to be no significant differences between the two sets of measurements. On the basis of these results, and in order to implement an institutional arrangement for long-term continuity of CO_2 standards, the NBS has agreed to distribute CO_2 Standard Reference Materials to the scientific community on a cost recovery basis. The gases will be available through the NBS Office of Standard Reference Materials, Gaithersburg, Maryland.

Tracers in the Ocean

The Transient Tracers in the Ocean (TTO) program, supported by NSF and DOE, is a large multi-institutional oceanic experiment that uses radioactive tracers derived from nuclear tests as well as man-made chemicals released to the atmosphere to monitor the manner and time scale of ocean mixing. The information obtained can be matched to the observed CO_2 distribution to help evaluate CO_2 uptake by the oceans.

The principal TTO field experiment in the North Atlantic Ocean in 1981 follows the Geochemical Ocean Sections (GEOSECS) Atlantic experiment of 1972. The time series and comparison of results are providing powerful information about ocean circulation which is then used for models of CO_2 removal by oceans and ocean-atmosphere climate dynamics.

One observed signal that may be of climatic importance is the marked decrease in salinity of North Atlantic deep waters in recent decades, as shown in figure 12. This freshening of the northern North Atlantic during the 10-year period is widespread; the changes are large and are outside the range of previous experience. The Labrador sea water mass was especially abundant, being almost 0.05 parts per thousand fresher and 0.25°C colder than previously observed. Although the exact causes of this change remain unknown, the findings may indicate climatic warming and resultant melting of polar ice.

The presence of deep ocean tritium and radiocarbon in the North Atlantic suggests appreciable bottom water formation in this region. The entire western North Atlantic north of 30°N has been penetrated by these nuclides. The front of the tritium tracer field has progressed from about 43°N in 1972 to 33°N in 1981, and occurs from the 1,800-m depth to the bottom. Since the mean age of the fossil fuel CO_2 increase is cur-

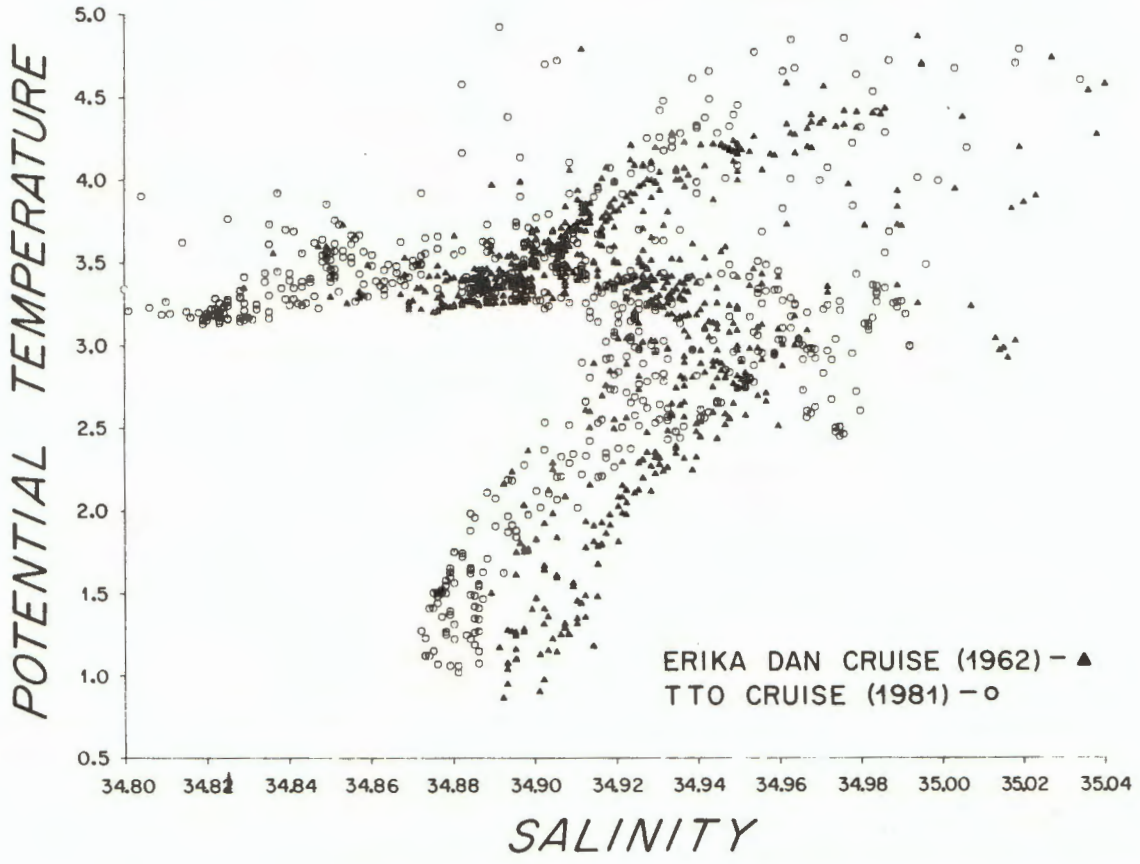


Figure 12.—Potential temperature vs. salinity scatter plot on a composite section across the North Atlantic at approximately 59°N for 1962 and 1981. Depths shallower than 100 m are excluded. Note the significantly lower salinities for the later cruise in the North Atlantic oveflow waters ($\theta < 2.5$°C) and the Labrador sea water ($\theta \sim 3.3$°C). (After P.G. Brewer et al., 1983).

rently about 28 years, the results of the TTO experiment give some indication of how much of the ocean interacts with the atmosphere on this time scale.

The carbon dioxide data set available from this experiment is substantial. Total inorganic carbon in sea water is about 2,000 micromoles per kg. Surface sea water today is estimated to contain about 35 micromoles per kg more CO_2 than in the past, and this excess diminishes with depth. Current model estimates suggest that the ocean has taken up about 40 percent of the fossil fuel CO_2 produced by man. The results of the TTO experiments are supporting this estimate.

Two major questions about CO_2 accumulations remain: Has a CO_2 induced warming been detected? How reliable are simulated climate models?

A working consensus among members has been reached that it is not yet possible to detect the warming expected from past growth of atmospheric CO_2. This position has been stated at international meetings dealing with detecting and monitoring climate change.

Several diagnostic studies (see MacCracken, 1982, for a review of such studies) have attempted to isolate the CO_2 warming signal in the 100-year temperature record by subtracting out other possible signals. Almost all studies claim to have seen a CO_2 signal. However, each investigator reduced the noise in his own way and several derived their own temperature record. Even the noise reduction techniques conflict. For example, Gilliland (1982) requires a measure of solar variability and volcanism to isolate a signal, while Bryson and Dittberner (1976) require only volcanism and tropospheric dust to isolate a signal. Further, some key features of the data set are difficult to explain. For example, Hansen et. al. (1981) fit the overall trend in the Northern Hemisphere record well, but their model does not reproduce the important 1960-75 cooling.

These results dictate the following: Key features of the data to be explained by a diagnostic analysis must be identified. The physical relationship for the other factors require research. For example, the research on the recent El Chichon eruption will provide data on volcanism. The current and planned satellite observations of the sun will provide data on solar variation.

A working consensus is also building that it is premature to draw firm, detailed conclusions from simulations of CO_2-induced climate change. This is based on research analyzing the capabilities, limitations, and prospects of mathematical climate models (NAS, 1982 and Schlesinger, 1982). Schlesinger compares, primarily, the general circulation models (GCMs) on temperature, precipitation rate, and soil moisture. These comparisons reveal similarities and differences among the GCM simulations, and some possible explanations for these differences. The models differ in their geography/orography, ocean modeling, and solar forcing, and because (for the simulations that can be rigorously compared) either equilibrium has not been reached, or the simulated climate changes are not all statistically significant (between model runs). These results go beyond the recent National Academy of Sciences study (NAS, 1982) in technical detail and implications for future research.

The implications of the research are:

- Additional factors (including seasonal cycles) must be analyzed and this may further reveal similarities and differences among models in their ability to simulate present climate.
- Further comparisons are needed to identify and understand the differences among model experiments. This requires comparability between experiments and detailed documentation of the experiments and control runs.
- The simulations need to be extended to assess statistical significance between model runs, particularly of variables other than temperature.

Climate and World Food Production

The Center for Agricultural Meteorology and Climatology of the University of Nebraska has developed a number of new programs aimed at supporting the state's agricultural enterprise by applying climate information. Two of these activities—the automated weather data network (AWDN) and the agricultural climate situation committee (ACSC)—and their interactions are prototypes of potential national programs.

Automated Weather Data Network

A cooperative agreement with the National Climate Program Office aimed at improving irrigation scheduling has provided the base for an automated weather data network that now has 17 stations that measure wind speed and direction, air temperature and humidity, solar radiation, soil temperature, and precipitation. The data are simultaneously archived and transmitted to AGNET, an interactive computer system for agriculture. (AGNET is described in the FY 81 annual report, pp. 11-12.)

Agricultural Climate Situation Committee

A committee of agricultural commodity specialists has been set up under the auspices of the Nebraska Cooperative Extension Service to provide up-to-date information and advice on climate conditions for the state's agricultural industry. This committee reviews weekly weather and climate data and prepares advisory bulletins on weather and crops, as well as the handling and transportation of livestock.

Climate Warnings

The U.S. Department of Agriculture/Weather Agriculture Outlook Board (WAOB) has increased and expanded its early warning capability by using NOAA/National Weather Service monitoring of global weather

events and crop impact assessments by WAOB agricultural meteorologists. A NOAA meteorologist at the Joint Agricultural Weather Facility devised a three-category snow cover approach using satellite data to aid the monitoring of winter kill of wheat until the World Meteorological Organization can secure routine transmission of snow depth data.

Fisheries

NOAA/National Marine Fisheries Service continued research on a wide range of climate-induced effects on size and distribution of fisheries. Because of the vulnerability of the early life stages of fish, research has concentrated on egg, larval, and juvenile phases. A good estimate of first-year survival is important for management of each year class as its enters the fishery. The Pacific Environmental Group (PEG) completed work on major ocean currents worldwide and air-sea interaction processes. The Atlantic Environmental Group (AEG) concentrated on similar problems associated with water mass movements and temperature variations in the Atlantic area, and specifically on the effects of migrant Gulf Stream eddies on fisheries. Fishermen are becoming increasingly aware of the value of the research in planning fishing strategies. They rely on the PEG and AEG temperature charts and analyses of ocean currents in searches for fish and shellfish.

III. National Climate Program Office Activities

The responsibility of the National Climate Program Office includes planning, oversight, coordination, and evaluation of the national program and reporting to the Executive Branch and the Congress.

Under the Five-Year Plan for conducting this program, most activities are to be implemented by the federal agencies. The NCPO, however, has responsibility for three (statutory) programs specifically mandated by the Climate Act. They are federal/state cooperative studies, development of experimental forecast centers, and international aspects of the national climate program.

FEDERAL/STATE CLIMATE PROGRAM

In 1980, at the request of NCPO, the Climate Board of the National Academy of Sciences established a panel on intergovernmental climate programs to assist NCPO in developing a program for federal and state cooperative activities in climate studies and advisory services.

The panel's report, *Meeting the Challenge of Climate*, was published in 1982 and had as its major recommendation that NCPO "take a leadership role in the development and support of a coordinated, nationwide system of climate services involving both the public and private sectors." Other recommendations were that NCPO: (1) complete the initial exploratory phase, (2) take the lead in coordinating federal agency participation and federal-state cooperation in providing climate services, and (3) develop approaches and incentives for bringing state and regional climate service systems into a nationwide system. The first phase of the program has been completed. Several states and private sector organizations undertook projects to determine user needs for climate services and to demonstrate approaches for providing climate information and service. Major emphasis has now shifted to supporting a smaller number of projects to develop the framework and some components of operational climate information service systems.

Ten federal-state cooperative climate projects were undertaken in the first three years of the program and are either completed or near completion.

1. "Public Utility Participation in the Intergovernmental Climate Program," San Diego Gas and Electric. The project explored ways in which a public utility and a local climate program might cooperate for mutual benefit.
2. "Development of Nocturnal Goes Data as a Source of Climate Information," University of Florida. This project demonstrated the feasibility of using infrared digital data from Goes to delineate seasonal surface climates. (Funding by Environmental Data and Information Service, NOAA.)
3. "Climate Information and the Land Use Planner," American Planning Association. A booklet was produced on current climate research that affects city planning.
4. "Design and Evaluation of the Feasibility of a Regional Intergovernmental Climate Plan," Michigan State University. This project explored the feasibility, value, and method of establishing a regional climate center in an area with active state climate programs.
5. "A Demonstration of the Utility of Climatic Information in Supporting an Irrigation Scheduling Program," University of Nebraska.
6. "Specialized Bin Data for Building Energy Analysis," W.S. Fleming and Associates. This project was set up to develop climate data sets for energy analysis in designing buildings.
7. "Development of a Concept for a Climate Information and Analysis Center for Pennsylvania," Lowell Krawitz and Associates. State agencies and private organizations were surveyed to ascertain their need for climate information and the ways in which it is currently obtained and used.
8. "Statewide Dissemination of Climatological Information via Educational Television," University of Oklahoma. Work concentrated on disseminating climate information via education and public television. The project developed a 20-minute video production, "Weather Modification: Hope for a Thirsty State."
9. "Assessing the Value of Climate Information: A Preliminary Intergovernmental Climate Program for Oregon," Oregon State University. This project used decision analysis techniques to assess the value of climate information in a few climate-sensitive decision making problems in Oregon.
10. "Demonstration of Use and Value of Climatic Information to Government Agencies," Illinois

State Water Survey. This new project, jointly funded by NCPO and the Climate Analysis Center, will provide new services, develop information, and increase awareness of the uses of climate data and information among state and federal government users.

Two state and two regional projects are now in progress:

1. "Colorado Demonstration—Intergovernmental Climate Program," Colorado State University. This project summarizes the uses of climate information in Colorado, identifies major users of this information, and defines the needs of various groups.
2. "The Initiation of a State Climate Program with Cooperating State Natural Resource and Education Agencies in Connecticut," University of Connecticut. This project has published the results of two comprehensive surveys of climate data sources in Connecticut and climate data use and users in Connecticut.
3. "A Regional Climate Coordinating Center," Illinois State Water Survey. The center is developing an infrastructure to coordinate climate studies, advisory services, and data management activities in several states and is working to improve the efficiency and effectiveness of the state climate centers.
4. "Northeast Regional Climate Program," Cornell University. A regional climate office was established at Cornell University. In addition to producing monthly state publications of climate data and information, the office is also the acquisition center for the entire northeast United States for the National Environmental Data Referral Service of the National Environmental Satellite, Data and Information Service.

The level of activity of state or regional climate service systems in the United States varies greatly. A few states now provide extensive climate-related services, but many states and regions have rather limited services. A few states provide no climate information service at all, relying instead on agencies such as the National Weather Service and on private consulting meteorologists and climatologists to provide such information as users may need. The entire approach to providing nationwide climate services will be addressed at a conference and workshop planned by NCPO for early 1983. Several projects are now being carried out to demonstrate aspects of climate information service systems which might be developed by state or regional organizations.

EXPERIMENTAL CLIMATE FORECAST CENTER

The Experimental Climate Forecast Center at Scripps Institution of Oceanography was established in April 1981. Since that time, experimental forecasts have been made of temperature and precipitation for each season for the conterminous United States. These use three different and independent forecasting procedures which are routinely tested and compared with forecasts using historical data. Production of forecasts is part of the research aims of the center, which are to develop and improve long-range prediction methods and examine ways to evaluate their performance.

The NCPO is proposing that another university-based Experimental Climate Forecast Center be established with joint industry-government support. Based on the progress of climate research in recent years, the potential of climate prediction for industrial and business applications is becoming increasingly obvious. A joint industry-government project can accelerate assistance in more rapid development and uses of applicable climate prediction methods and products by the private sector. Meetings are being held to discuss collaborative efforts.

INTERNATIONAL ACTIVITIES

The NCPO coordinates international climate-related activities, specifically, the U.S. role in the World Climate Program. Because climate is global, the National Climate Program Office encourages an exchange of international expertise and data.

The NCPO maintains an active liaison with the Climate Research Committee (CRC), which is under the newly formed Board on Atmospheric Sciences and Climate of the National Academy of Sciences. The CRC meets two or three times a year to review and advise government on matters relating to U.S. climate research, and to set priorities for climate research programs.

The NCPO is the U.S. focal point for the International Satellite Cloud Climatology Project. The plans for the ISCCP have been briefly presented in previous annual reports and although they have undergone intensive national and international review within the past year, they remain essentially the same. The ISCCP is scheduled to begin in July 1983, with the United States playing a major role in processing Goes and Tiros-N data as well as merging the global data set, producing the cloud parameters for the project, and archiving the ISCCP data set. The NCPO, along with Dr. Robert Schiffer of NASA, the international project manager, is working to develop the U.S. role in the ISCCP.

Plans continue in the United States, primarily through NOAA, for a large-scale, ocean-atmospheric interaction study in the Pacific and Indian oceans beginning in FY 84. The project, alternately known as El Nino-Southern Oscillation study (ENSO) or the ocean-atmosphere climate interaction study (OACIS), is presently multinational but should become the major part of the World Climate Research Program's study of the interannual variability of the tropical oceans and global atmosphere

(TOGA) when that program begins. Plans for TOGA will be presented to the World Meteorological Organization Congress in May 1983 for approval as part of the World Climate Research Program.

In August 1982, a project was begun involving the World Climate Data Program, the NCPO, and the Oklahoma Climatological Survey. Its purpose is to demonstrate to less developed countries the use of climate data with a microcomputer. The project is in three phases: phase 1 will develop software modules for microcomputers which will ingest meteorological data, compute simple statistics, including climatological summaries, various indexes, etc., and display them on a cathode ray tube; phase 2 will demonstrate the microcomputer system at WMO meetings, including WMO Congress and the Regional Technical Conference on Climate for South America; and in phase 3, the computer system will be installed in less developed countries upon request. The initial phases of the project are expected to last about one year, with the final phase taking several years to implement.

The seventh joint meeting of Working Group VIII, the US-USSR Agreement on Cooperation in the Field of Environmental Protection, took place in Moscow, Yalta, and Leningrad, USSR in October and November 1981. During 1982, fifteen U.S. scientists visited the Soviet Union and one USSR scientist visited the United States to discuss climate-related projects within their countries. These included eight U.S. scientists who attended a symposium on paleoclimatology at the 11th INQUA Congress (International Union for Quarternary Research) in Moscow during July and August. In addition, major progress was made on joint monographs on the climates of the Pleistocene and Holocene eras. The monographs are expected to be available by mid-1983.

A five-man delegation went to China in September 1982 to discuss activities in the ocean climate field under the US-PRC bilateral in marine and fishery science and technology protocol. This was the first time discussions within this bilateral dealt with climate-related activities, centering mainly on large-scale air-sea interactions and physical oceanography. Five areas were identified as a basis for activities within the bilateral agreement during the upcoming year. These include: exchange of scientists in ocean climate studies, expanded use of expendable bathythermographs via voluntary merchant ships, a project to assess the impact of climate on marine fisheries, a program on drifting buoy observations and technology transfers, and a program on hydrographic sections and moored current meter arrays that would be part of the TOGA project.

A meeting on the US-PRC bilateral on cooperation in atmospheric science and technology took place early in FY 83. Among the cooperative projects planned for the coming year are comparison studies of climate and agriculture of the North China Plain and the North American Great Plains, a workshop on monsoon research, a symposium on Tibetan Plateau and mountain meteorology, a discussion on possible joint paleoclimate studies, bilateral projects related to the WCRP TOGA program, and continued activities under the training and participation program.

IV. Evaluation

National Climate Program activities have for the most part followed the general direction of the NCP Five-Year Plan. However, progress toward the goals of the program has been uneven because changes in funding have forced changes in the timetable for implementing parts of the plan. A review of the major categories and their status in terms of planning and implementation is given below.

PROVIDING CLIMATE PRODUCTS

Generation and Dissemination of Climate Information

Lead Agency: NOAA/EDIS

The milestones for FY 1982 were to:

- Initiate serial publication of topical and regional data catalogs (inventory supplements).
- Establish guidelines for state participation in local acquisition and processing of local climate data.
- Complete design of a long-term national climate data/information system.
- Sponsor, with the World Meteorological Organization, a planning conference on climate data inventories and information systems.

The primary effort in FY 82 in this area has been in building the climate data base and making it more accessible to users. Procedures have also been started to improve the quality control and processing techniques for much of the routine data received at the National Climate Center. A number of new climatological data products were issued during the year, usually in response to user requests.

EDIS has been working closely with state climatologists to improve the services provided. Two new states, Vermont and Maine, have appointed state climatologists. Plans to improve coordination between state and federal data collecting and archiving functions should be developed during 1983.

EDIS has also continued the development of a climate data and information clearinghouse by updating and expanding the Interim Climate Data Inventory and making it accessible on a national on-line information retrieval system. Feedback from users will help in developing the system further.

Although there was no international planning conference with WMO on climate data inventories and information systems, EDIS has provided the World Climate Program Department with detailed information on the U.S. national climate data inventory for use in the WMO data referral system called INFOCLIMA. Data experts from NCC, CEAS, and CAC also participated in several international meetings sponsored by the World Climate Program Department and were asked to help develop the data and applications components of the World Climate Program.

Solar and Earth Radiation

Lead Agency: NASA

The 1982 milestones were to:

- Define a long-term solar monitoring program.
- Use earth radiation budget and cloud data sets as initial conditions for climate model experiments and validate and improve those models. Use improved models for further sensitivity studies.
- Improve the numerical description of the effects of clouds in the hierarchy of climate models.

All of these milestones have been met, but to varying degrees. Solar irradiance measurements from the Solar Maximum Mission (SMM) have proved very valuable, both in providing a basis for a second generation instrument being proposed for the upper atmosphere research satellite (UARS), and in delineating the need and requirements for a long-term solar irradiance monitoring program.

Various uses of Nimbus-7 ERB data sets for radiative transfer models and cloud climatology modeling efforts have supported continued development of the International Satellite Cloud Climatology Project and ERBE. Much of the operational processing for the Nimbus-6 ERB data sets has been delayed for funding reasons: this work now is to be done following completion of the Nimbus-7 data sets. The Nimbus-6 data will still be able to provide a long-term continuous data base.

Special studies directed at measuring sensitivity and climate boundary conditions have also been delayed for financial reasons: notable among these are studies related to hydrologic cycle, sun-climate relationships, air-sea interaction, and to some extent, cryospheric

processes (snow, sea ice, ice sheet). Studies of extended cloudiness, radiation, and aerosol properties and processes have evolved primarily because of their role in the NCP principal thrust. Cloud classification and parameterization have been particularly well addressed in preparation for model validation and sensitivity testing, and for long-term preparation for ISCCP data retrieval, archiving, and dissemination.

The volcanic aerosol data sets and modeling that followed the Mount St. Helens eruptions have, to some extent, laid the groundwork for studying the potentially significant impact of the El Chichon eruptions, both as a climate sensitivity perturbation experiment and as an opportunity to extract aerosol data from satellite instrument systems. A continuing study of the El Chichon cloud is under way.

The most important FY 1982 achievements in the study of solar and earth radiation are:

- Extended high-resolution solar irradiance monitoring and attendant radiative transfer modeling in support of ERBE development.
- A pilot study to compare alternative satellite data analysis techniques for retrieving cloud physical properties from remotely sensed radiances as preparation for the ISCCP.
- The coordination of monitoring and data-gathering missions for understanding the evolution of the El Chichon stratospheric aerosol cloud and its impact on the climate system.

Several other studies directly related to developing an improved understanding of cloud/radiation processes and to formulating a comprehensive global cloud climatology are in progress. This work is of a continuing nature and provides a framework for designing studies of cloud parameters. The efforts include classification studies (in which techniques for remote sensing of cloud parameters and their variations over time and space are developed), radiative transfer modeling of specific cloud fields, sensitivity studies of these models, and aircraft observations for collection and validation of cloud properties.

CLIMATE RESEARCH AND PREDICTION

Ocean Heat Transport and Storage

Lead Agency: NSF

No specific milestones were established for 1982. Work continues on planning activities for major programs in ocean monitoring, studies of ocean-atmosphere interactions, and ocean circulation. There is a working consensus that two major efforts are feasible and required at this time: A study of large-scale ocean-atmosphere interaction associated with El Nino and the Southern Oscillation, and a world ocean circulation experiment. Plans for the first program have been developed and will be initiated in 1984; they will build upon existing ocean climate activities, such as EPOCS. Plans for the world ocean circulation experiment require further study and are dependent on available satellite observational systems. Planning must begin now for the program if it is to take place beginning in the late 1980s.

The specific need for satellite-borne sensors with the capability to measure sea-surface topography and wind stress has been stated several times in national and international scientific meetings. The success of large-scale climate research programs depends heavily on the availability of adequate global satellite observations. Several groups are presently looking at the detailed needs for satellite data for climate research; the results will be submitted to NASA and OMB as they are available.

Efforts are under way to continue gathering important data in the North Atlantic which can provide indications of climate change following the recent discoveries of freshening of the deep water using data from the TTO program.

Climate Prediction and Analysis

Lead Agency: NOAA/CAC

The FY 1982 milestones for this principal thrust were to:

- Test mid-latitude, objective predictions based on new types of external predictors.
- Based on predictability studies, evaluate the opportunity for extending the lead time of seasonal outlooks.
- Initiate distribution of a "World Climate Bulletin" containing recent and current climate indexes and global climate analyses for use by those engaged in impact assessment, experimental or operational prediction, and diagnostic studies.
- Adapt satellite methods for monitoring ocean and land surface processes.

Overall progress in developing and testing objective mid-latitude predictions based on new types of external predictors has been good. Of particular note: New equations for monthly surface temperatures derived from 700-mb anomalies were installed for operational use. The assessment of point and field significance of lag correlation charts was improved. Antecedent Southern Oscillation indexes were incorporated into the operational prediction. Parallel testing of three methods continued at the Experimental Climate Forecast Center. Statistical forecast models using new predictors were developed there.

Significant progress has also been made in the development and testing of dynamic-numerical models.

Several research studies aimed at extending the lead time of seasonal outlooks have been undertaken. The Climate Analysis Center's operational prediction techniques were extended for two to eight seasons in advance

and modest positive skill was demonstrated on the first set of cases. Scripps Institution is evaluating forecasts made two seasons in advance. Statistical methods to support longer lead-time predictions are being developed.

The Climate Analysis Center has developed the operational capability to systematically document climate anomalies. A *Weekly Climate Bulletin* locates and describes important anomalies in temperature and precipitation. Quarterly review articles describing the global circulation patterns and anomalies in the ocean-atmosphere climate system are circulated through publication in the *Monthly Weather Review*. The CAC is now issuing special climate diagnostics bulletins which describe in detail specific large-scale climate anomalies, their movements, and evolution. In addition, a computer-based climate anomaly monitoring system (CAMS) is under development. This will further improve the identification and monitoring of significant climate anomalies.

The satellite has become an important tool in monitoring the global climate system. A large segment of the climate diagnostics data base, upon which the monitoring is based, utilizes satellite-derived data, including global radiation budget and fluxes, sea surface temperatures, snow cover, soundings, cloud motion vectors, and precipitation indexes. In addition, satellite-sensed surface temperatures are used regularly to assess extensive freezes in agricultural applications.

CLIMATE IMPACT AND POLICY

Carbon Dioxide, Environment and Society

Lead Agency: DOE

The milestones for 1982 were to:

- Complete a feasibility test of remote methods for biomass measurements.
- Complete North Atlantic cruises and measurements of the Transient Tracers in the Ocean program.
- Make preliminary estimates of climate sensitivity available from coupled ocean/atmosphere general circulation models.
- Sponsor an international meeting on carbon dioxide, environment, and society with sections on research, assessment, policy development, and public outreach.

Preliminary results indicate that satellite remote sensing and computer data processing can be used to detect changes in land use. Landsat images have made it possible to detect changes over a five-year interval, with an error of about 1-2 percent for large areas (400 to 500 hectares) and about 10 percent for smaller areas. However, it is difficult to obtain ground corroboration of changes in many apparent forested areas (determined from satellite imagery) because there are no aerial photographs or actual ground observations.

It is not clear whether it will be feasible to use satellite remote sensing methods to measure biomass change. To do this, it will be necessary to combine the methodology for detecting areal changes with other data or assumptions about biomass changes for the land units under investigation. This coupling is being explored for several tropical forests where synchronous Landsat images, ground-truth data, and biomass statistics are available.

The Transient Tracers in Oceans program is on schedule. The planned cruises of the North Atlantic ocean have been completed as well as many measurements of hydrographic properties and of some carbon constituents of surface and deep ocean water. Measurements of tracers and interpretation and modeling of data will continue, as planned, into the fourth year of the North Atlantic TTO program. This program was expanded in 1982 to include the equatorial Atlantic region and thus provide a more comprehensive data base for modeling CO_2 uptake and circulation in oceans.

Preliminary estimates of the CO_2-induced climate change from coupled atmosphere-ocean general circulation models are available. Manabe and Stouffer (1980) conducted an experiment with a fourfold increase of atmospheric CO_2 which showed a decrease in climate sensitivity to CO_2 compared with previous experiments by the Geophysics Fluid Dynamics Laboratory. Washington (1982) is conducting experiments with a two-fold increase in CO_2 with computer-generated clouds, annual solar cycle, and a fixed-depth mixed layer ocean. Preliminary results show an increased sensitivity when compared with previous experiments by the National Center for Atmospheric Research. The above differences most likely are caused by the temperature of the control experiments, sea ice treatment, cloud treatment, and the addition of the annual solar cycle. The two conclusions reinforce the need for comparable experiments and of a more completely modeled climate system.

Two international meetings on carbon dioxide were held during 1982: the Coolfont Conference on "Carbon Dioxide, Science and Consensus" which brought together scientists and government and international organization representatives, to consider the present CO_2-climate information base, research requirements, and assessment activities; and "The International Conference on Rising CO_2 and Plant Productivity," which considered the current state of knowledge about plant responses to various CO_2 concentrations up to 600 ppm.

Climate and World Food Production

Lead Agency: USDA

The milestones for 1982 were to:

- Continue ongoing activities in support of U.S. and world food assessments.
- Carry out additional requirements studies and technical planning for future program options.

- Initiate work on one or more optional program efforts.

The Agricultural Research Service (USDA) continues to work on understanding the basic responses of plants to environmental changes. The studies include climatology of dry-day frequencies, short period rainfall intensities, hot wind effects, elevated CO_2 levels, changing soil tillage practices, and varying levels of ozone concentration, to mention a few. Significant work continues in developing and evaluating simulation models for assessing plant-soil-atmospheric interactions and remote-sensed data.

The Cooperative State Research Services (USDA) has continued work in the regional programs for agricultural meteorology and climatology. The coordinated regional program now covers the entire United States.

The Soil Conservation Service (USDA) snow surveys are done in cooperation with NOAA/NWS, to estimate snowmelt runoff and its effect on irrigation water supplies and stream flow levels. Testing continued on a system of 500 collection platforms designed to monitor snow conditions and telemeter the data to two ground receiving stations. Soil moisture monitoring in seven states provides data for use in verification tests of soil, plant, air, and water models.

The Statistical Reporting Service (USDA) is studying the sensitivity of yield forecast models to the distribution of environmental observation points, i.e., the NOAA cooperative weather station network.

USDA and NOAA have finished a draft of the umbrella plan for the nation's agricultural weather services. Major areas of responsibility for the cooperative work between NOAA and USDA are indicated and the plan is being reviewed.

TECHNOLOGICAL AND SCIENTIFIC ISSUES

In the FY 1981 annual report, several technological and scientific issues were presented which need to be addressed in the near to intermediate term. Through a series of national and international meetings, some progress has been made on some of these issues, such as development of strategies for detecting climate change, plans for further development of climate data bases and improving their accessibility, definition of needs for improved satellite technology, etc. However, these issues were not resolved in FY 1982 and many of these needs will form the basis for an update of the NCP Five-Year Plan in FY 1983.

RECOMMENDATIONS FOR CHANGES IN LEGISLATION

Experience in carrying out the national climate program has revealed areas in which the program could be strengthened by amending the National Climate Program Act, which established the program in 1978. The Department of Commerce recommended amending the National Climate Program Act in several areas to improve the efficiency and effectiveness of the program. Some of these recommendations were incorporated in H.R. 6324, "Atmospheric, Climatic, and Ocean Pollution Act of 1982" which was passed by the House of Representatives in August 1982. However, the U.S. Senate did not complete action on its bill to amend the climate program, S. 2605, "National Oceanic and Atmospheric Administration Act" which was similar to H.R. 6324.

V. Summary of FY 1982 to FY 1984 Budgets

The National Climate Program Act requires that the Office of Management and Budget (OMB) review the agencies' request for climate activities as an integrated, coherent, multiagency request. OMB Circular A-11 requires agencies to forward their climate budget data to the NCPO in parallel with submission to OMB. NCPO then compiles the data and prepares an analysis of agency requests in terms of the requirements of the Five-Year Plan. This analysis is based upon data available to NCPO and the Climate Program Policy Board as of mid-September, and focuses primarily on new initiatives for the forthcoming fiscal year.

The distribution of resources by agency for climate research and services for FY 82 through FY 84 is shown in table 1. In table 2, the existing base program is subdivided into the major categories of the National Climate Program (NCP). Both tables 1 and 2 show that in FY 1984, there will be a decrease in total program funding. This decrease is due to NASA's completion of the Earth Radiation Budget Experiment (ERBE) satellite system, a $1.6 million reduction in NOAA's participation in the World Climate Program, and a $1.7 million decrease in the Department of Interior. Despite the above decrease in program content, the DOC/NOAA budget shows a $2.5 million increase from FY 82 to FY 83. This is due to a revision of NOAA's budget, which now includes certain overhead costs not previously included in past analyses. The FY 83 NOAA base program budget is therefore larger in dollar amount than FY 82, but is actually reduced in terms of total effort. For the national climate program as a whole, there continues to be a high degree of coordination and joint funding in areas of mutual interest among agencies.

The NCPO has analyzed trends in the base program over the past several years. Table 3 compares the range of budget levels anticipated in the Five-Year Plan with base program budget requests for fiscal years 1982-84. For most categories, the FY 82-84 budget requests are within the range anticipated by the plan. The major exception is the area of data management. The plan anticipated that about 13 percent of the total effort would be directed to this area whereas the share is only about 8 percent. An adequate national data base is critical to efforts to better understand, respond to, and eventually predict climate fluctuations and their impact on various sectors and activities. National data archives are thus a valuable national resource; improving their accessability and their comprehensiveness is an important federal role. In the future, advances in communication and information systems should be introduced in data management to handle climate data as has recently been done at NCC. Needs and opportunities in data management must be evaluated in light of modern technologies. The NCPO will continue to follow carefully this aspect of the NCP and advise OMB on future needs.

Table 1. Agency Total Base Program

	FY 82 Base	FY 83 Plan	FY 84 Req.
Agriculture	15.8	16.3	16.3
Commerce	30.3	31.3	31.9[a]
Defense	10.2	11.4	12.2
Energy	13.5	9.1	12.5
Interior	4.8	3.4	3.1[b]
NASA	31.9	33.9	26.0[c]
NSF	34.7	36.9	38.3
Total	141.2	142.3	140.3

NOTE: Variance in totals due to rounding off.

[a] Increase due to restructuring the NOAA budget to include additional overhead items not previously included.

[b] Decrease primarily due to discontinuance of the Hiplex project in the Bureau of Reclamation.

[c] Decrease mainly due to completion of the Earth Radiation Budget Experiment satellite systems.

Table 2. Base Program Cross-Cut

	FY 82 Base	FY 83 Plan	FY 84 Req.
Impact Assessment			
Agriculture	11.6	12.1	12.1
Commerce	1.8	1.8	1.8
Defense	—	—	—
Energy	4.5	3.2	5.2
Interior	0.9	1.1	1.2
NASA	—	—	—
NSF	0.7	0.9	1.0
Subtotal	19.5	19.1	21.3
Climate System Research			
Agriculture	—	—	—
Commerce	10.4	10.4	12.8
Defense	2.0	2.0	2.5
Energy	9.0	5.9	7.3
Interior	2.3	0.7	0.6
NASA	2.0	5.2	5.2
NSF	28.5	30.0	32.6
Subtotal	54.2	54.2	61.0
Observations			
Agriculture	1.5	1.5	1.5
Commerce	7.4	8.5	6.9
Defense	—	—	—
Energy	—	—	—
Interior	—	—	—
NASA	29.1	28.1	20.2
NSF	4.9	5.2	2.7
Subtotals	42.9	43.3	31.3

	FY 82 Base	FY 83 Plan	FY 84 Req.
Data Management			
Agriculture	0.5	0.4	0.4
Commerce	6.5	6.5	6.5
Defense	0.7	0.7	0.7
Energy	—	—	—
Interior	1.6	1.6	1.3
NASA	0.8	0.6	0.6
NSF	0.6	0.8	0.8
Subtotal	10.7	10.6	10.3
Analysis and Projection			
Agriculture	1.6	1.7	1.7
Commerce	1.1	1.0	0.7
Defense	—	—	—
Energy	—	—	—
Interior	—	—	—
NASA	—	—	—
NSF	—	—	1.2
Subtotal	2.7	2.7	3.6
Information Services			
Agriculture	0.6	0.6	0.6
Commerce	2.0	2.0	2.0
Defense	7.5	8.7	9.0
Energy	—	—	—
Interior	—	—	—
NASA	—	—	—
NSF	—	—	—
Subtotal	10.1	11.3	11.6

NCPO	1.1	1.1	1.2
TOTAL	141.2	142.3	140.3

NOTE: Slight variance in totals are due to rounding off.

Table 3. Budget Analysis 1980-84 (percent of total dollars)

	Five Year Plan	FY 81 Analysis	Projection 1982-84
Impact Assessment[a]	20-23	19	20
Research	29-36	36	35
Observations	34-22	30	31-27
Data Management	13	9	8
Information Services and NCPO	8-6	6	7

[a] Includes DOD reported information services.

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SFS/6/10/84 *

NUCLEAR WINTER AND NUCLEAR FREEZE

Does the Nuclear Winter scenario compel a Nuclear Freeze? Does the prospect of human extinction through a climate freeze following a nuclear war make it compelling for the major nuclear powers, the US and USSR, to stop increasing their existing nuclear arsenals?

Put in these terms, the answer doesn't seem difficult. And indeed, the Nuclear Freeze movement, a political-action-oriented mass movement, has added the nuclear winter scenario to its existing simple argument, namely that the current nuclear arsenals are already too large, able to destroy cities many times over. The worldwide freezing temperatures anticipated from the nuclear winter scenario -- the climate freeze -- seem to suggest, semantically at least, the freezing of nuclear arsenals. This is a simplistic association, yet it can be very effective with people who, already frightened by the prospects of a nuclear war, are exposed to TV spectaculars such as "The Day After".

This is not the place to enter into a full-scale discussion of the modalities of nuclear and general disarmament. It should be sufficient to point out, however, that the nuclear freeze movement gets Soviet approval because it is in line with two major Soviet policy objectives, namely the preservation of their

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existing quantitative nuclear advantage (when measured both in total megatons and number of strategic weapons) and their fear that the US may be perfecting smaller and more efficient weapons for strategic as well as tactical applications.

One needs to keep in mind further that a nuclear freeze is exactly that; a standstill agreement, and not an agreement to "build down" nuclear armaments. The Soviet Union has broken off disarmament negotiations with the United States, presumably to avoid moves towards nuclear parity.

I don't want to suggest that the average supporter of a nuclear freeze is a Soviet "dupe" or even a Soviet agent; but there is no question of the parallelism between a freeze and Soviet political aims. That may explain the wide publicity given to the nuclear winter scenario within the USSR, as well as the easy availability of top Soviet scientists (of the correct political persuasion) for international gatherings devoted to the cause of a nuclear freeze and nuclear winter.

To be sure, many US scientists are fully aware of the reasons for the Soviet activity, but see the nuclear freeze as a tactical step towards an actual reduction of nuclear arsenals. Whether or not lower levels of weapons, in fact, promote stability and therefore make nuclear war less likely is, of course, a hotly debated question which forms the kernel of the whole issue of disarmament.

THE NUCLEAR FREEZE FORUM

With this preamble out of the way, I can now address the Joint American-Soviet Scientific Forum on Nuclear War, entitled The Worldwide Consequences of Nuclear War. It was organized by the Nuclear Freeze Foundation, headquartered in Washington, D.C., and held at the Russell Senate Office Building on December 8, 1983.

The forum had all the trimmings of a "media event": Two U.S. senators (Kennedy and Hatfield) who are known opponents of the current US government policy; two popular scientists (Sagan and Ehrlich), well-known through television, books, and magazines; and the presence of prominent Soviet scientists (who seemed to have had no difficulties in getting permission to leave the Soviet Union to participate in what amounts to a political performance). All of this focused on a topic of great public concern, with nary a voice of dissent from the eight assembled scientists -- although there seem to have been disturbances in the audience. (The record shows the chairman calling for the eviction of persons who tried, in vain, to put rather pertinent questions to the Soviet scientists.)

Senator Kennedy's opening statement expresses his basic philosophical difference with the White House: He puts abiding faith in a Summit meeting between the leaders of the United States and USSR, and he chides the Administration for regarding nuclear war as survivable. He attacks this view as expressed in a study of the Federal Emergency Management Agency:

"This kind of thinking makes nuclear war more likely because it makes nuclear war seem more bearable. The inescapable truth is that the firing of even a fraction of the Soviet and American arsenals would turn the Northern Hemisphere into a cold desert and whole earth into a dying planet."

This paragraph tells all. A desperate desire to believe in the nuclear winter scenario because it would turn a nuclear exchange, or even a massive first strike, into Armageddon. (Senator Kennedy does not enquire into the consequences of a small first strike, say against a single city.)

He equates the nuclear winter with the Doomsday machine, invented some years ago by the late Herman Kahn, a device designed to retaliate automatically so that the attacker would essentially commit suicide. Kennedy wants to "tell... the world about the suicidal nature of nuclear war..."

He expresses a faith in scientists and scientific truth which is surprisingly naive:

"Today, we will hear about that truth in all its grim reality from the most respected scientists in both countries. They will review new facts about the utterly devastating effects of a nuclear exchange on both climate and biology. Whatever our differences in forms of government or systems of ideology, there is broad agreement among

scientists about this issue. Science is not based on political preference or propaganda, but on proofs and facts. Science doesn't lie, and the scientists who are with us today, no matter where they come from, are united in their commitment to scientific truth."

Yet when Kennedy presses Prof. Sagan

"You are suggesting that all the other scientific evaluations of the studies that have been done, more than 100 studies, support the conclusions which you have reached."

Sagan admits only to "differences on points of detail". He also imagines a rather sharp threshold in terms of sunlight-absorbing smoke, although "we do not know precisely where this threshold is" (in terms of megatons exploded)." ... a convincing first strike ... would very likely trigger the nuclear winter."

But conclusive and sure evidence is not available to make a judgement about the climatic aftereffects of a nuclear exchange. At best, a certain probability can be attached to the occurrence of a world-wide freeze as a result of

smoke from fires started by nuclear explosions. There is disagreement both about the probability of a nuclear winter and about the threshold at which possible climatic effects would become of worldwide importance. (See Fig.) In particular, the results of calculations by Professor Vladimir V. Alexandrov, pesented at the Forum, do not provide any kind of independent confirmation of Sagan's work. Alexandrov explicitly accepts the physical model of the Sagan group and therefore derives rather similar consequences.

In Sagan's own words: "Apocalyptic predictions require, to be taken seriously, higher standards of evidence than do assertions on other matters where the stakes are not as great."(1)

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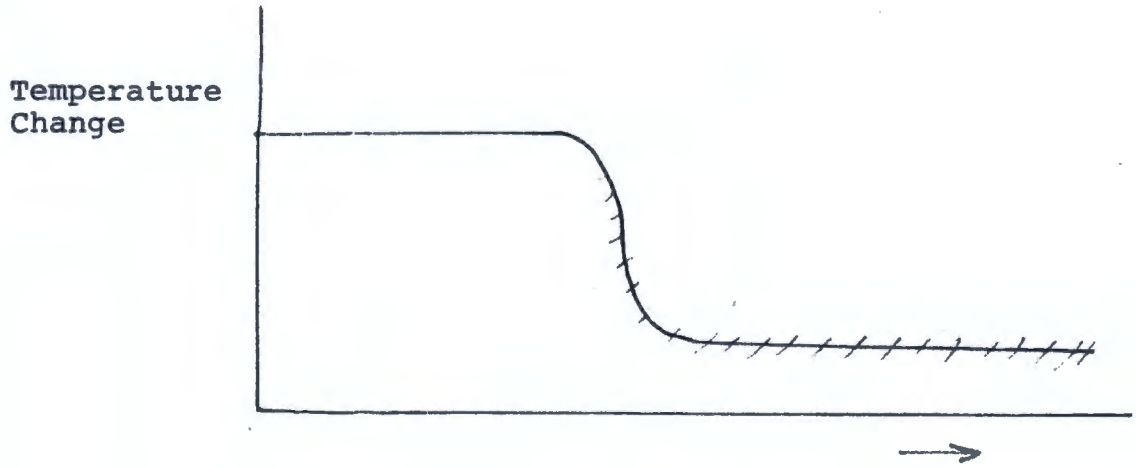
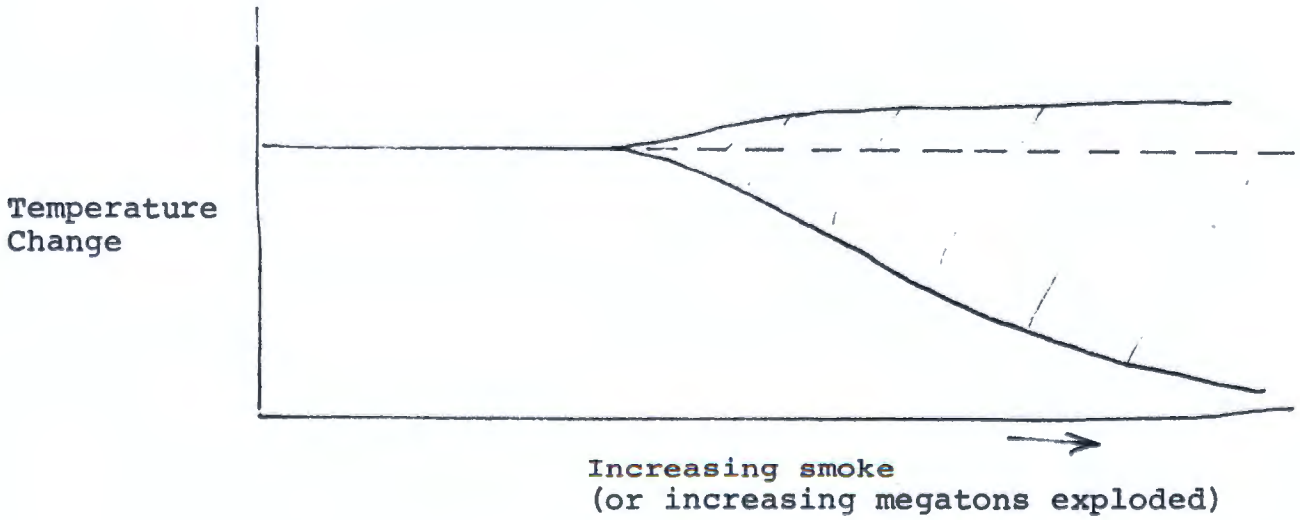
(1) Carl Sagan, "Nuclear War and Climatic Catastrophe: Some Policy Implications" Foreign Affairs, Winter 1983/1984.

I do not believe that such standards have been met. Nevertheless, since the probability of a nuclear winter scenario is finite -- that is, greater than zero -- it is important to consider its strategic implications, particularly as it relates to the relative effects on the Soviet Union and the United States,



The TTAPS view (Ref. 2) of climate effects visualizes a high probability of a global temperature decrease.



An alternative view (Ref. 3) visualizes a rather broad threshold and a temperature change which could even lead to transitory warming. The range of possibilities is wide; a modest cooling is more likely than either a freeze or a warming.

as well as on the rest of the world including the southern hemisphere. The consequences to the various countries involved appear to be sufficiently different to affect nuclear strategy as well as their political actions. Before discussing these differential effects of a nuclear winter scenario, we will review, briefly, the uncertainties surrounding such a scenario.

THE NUCLEAR WINTER SCENARIO

It was recognized from the very beginning that nuclear weapons, in addition to being much more powerful, are qualitatively different from conventional explosive bombs which produce blast effects and heat. There is the emission of radioactivity in the form of direct radiation which has its effect immediately in the vicinity of the explosion. There was discovered the problem of "fallout", radioactivity which is conveyed by the wind and can affect quite distant points sometime after the explosion. In the early 1970's, it was discovered that nuclear detonations could produce effects on the upper atmosphere and lead to the partial destruction of ozone in the stratosphere. The implications are that enhanced ultraviolet radiation, now shielded by the ozone layer, would be able to penetrate towards the surface of the earth and cause biological damage to people, animals, and plants.

Nuclear explosions cause fires as the heat radiation from the fireball ignites combustible materials. Among the first studies that I know of is that by Prof. Robert Ayres.

During the years 1962-1965 at the Hudson Institute in New York State, he calculated the fires produced by a nuclear explosion and also pointed, quite correctly, to the fact that the smoke would absorb solar radiation and could thereby cause darkness and lower temperature at the surface of the earth. His three-volume study published in 1965, however, attracted little attention and the matter was forgotten until quite recently.

What stimulated renewed interest was the discovery that dust storms on the planet Mars produce lower surface temperatures; that dust emitted by volcanoes into the stratosphere leads to cooling at the earth's surface; and most particularly the hypothesis put forward by Prof. Louis Alvarez and his colleagues that the impact of a meteorite about sixty-five million years ago projected sufficient dust into the atmosphere to block out the sun and cause enough cooling to wipe out the basis for life support for the dinosaurs. In 1982, Paul Crutzen and J. Birks then pointed out that a full nuclear exchange could produce sufficient smoke and soot to cause an equivalent effect on the earth. This idea was developed in much greater detail by Prof. Carl Sagan and his colleagues Turco, Toon, Ackerman, and Pollack. Their paper published in Science magazine in December 1983, generally referred to as TTAPS, has stimulated much of the present discussion.[2]

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(2) R. P. Turco et al. "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions" Science 222, pp. 1283-1292, 1983.

The TTAPS paper has virtues and faults. It is the most detailed study currently available on the climatic aftereffects of a major nuclear exchange. It makes use of a large but incomplete data base and several physical-atmospheric models back-to-back, some well-tested, others inadequate. But because this study is detailed and well-documented, it is also easiest to criticize. A major critique must be that it does not indicate the wide range of uncertainty that exists in the outcome -- because of problems with the basic assumptions, the fundamental data, and the validity of the models.

This is not the place to have a scientific interchange; but the scientific journals will be full of discussions which will question, support, or amend various aspects of the nuclear winter hypothesis. This is as it should be. A large number of specialists in different areas will find fault with one aspect or another and will contribute their expertise through the process of criticism. Some of them, like myself, will simply point out aspects that have been overlooked and need to be fully considered; others will furnish detailed studies which will complement or supplant the TTAPS study in one area or another.

All of this scientific discussion will eventually focus down on two sets of issues. First: How serious is the nuclear winter effect in terms of temperature change, time duration, and geographic extent? Will there be sub-freezing temperatures

covering all of the world [except the ocean and coastal regions] for many months or longer; or will there be a slight depression in temperature covering the inland continential regions; or could there even be a warming in some areas and a cooling in other areas as a consequence of the fact that the smoke clouds are not uniform.

Secondly, what is the threshold for climatic effects? This "threshold" cannot be a very precise number in terms of megatons or warheads exploded, but will depend on how they are exploded, at what altitude, at what locations, at what time of the year, against what targets, etc.

Most important: How serious are the ecological impacts on plants, animals, and especially on human beings in different parts of the world?

I fully expect that the threshold will turn out to be quite broad -- and this is of importance for strategic reasons. I also expect that there will not be any consensus soon on the climate effects themselves; rather people will assign widely differing probabilities to different scales of the effect. I further expect that with time, as we have more scientific discussions, the range of probabilities which, right now, might range from close to zero percent to nearly one hundered percent will narrow somewhat.

One thing is certain: The nuclear winter scenario will be a boon to atmospheric researchers everywhere -- in the United States, the USSR, and the rest of the world, as government

support for atmospheric studies increases. Not only research on global climate change, but also more detailed studies of mesoscale meteorology, cloud physics, fire phenomena, will expand. We have some recent experience to fall back on. The controversy about the supersonic transport which swirled around the United States in 1970-71 led to an ambitious research program on the chemistry of the stratosphere, and particularly on what happens to ozone. In turn, this research program has given us a basis for gauging other important environmental consequences on the stratosphere quite unrelated to supersonic transports.

NUCLEAR WINTER IMPLICATIONS

In spite of the uncertainty about the reality of the nuclear winter scenario -- its magnitude, time duration, geographic extent, and the threshold at which climatic phenomena would become important -- the probability of a nuclear winter effect must be factored into strategic thinking. My conclusion is that the nuclear winter scenario is bad news for the Soviet Union. Specifically, a Soviet attack is more likely to create a nuclear winter than a U.S. attack. Further, the Soviet population is likely to be harder hit by the effects of a nuclear winter than Americans.

The initial thinking has been fairly crude. It assumes or implies a well-defined threshold which is easily reached by even a minimal nuclear exchange scenario. It derives catastrophic consequences to all humanity.[1] This zero-order treatment of the problem leads to the seductive conclusion that nuclear war is unthinkable and will not happen because it would destroy also the nation who carries out a first-strike surprise attack. This doomsday scenario is attractive because no one really wants a nuclear war. The tendency, therefore, is not to delve further into either the assumptions that went into the construction of the nuclear winter scenario nor into the reasoning that led to this conclusion.

Unfortunately, it is necessary to be a little more precise. Specifically, since the climate effects cover a wide range

of possibilities -- from slight warming all the way to deep freeze, with the probabilities for each scenario not known[3] -- we must pay attention to the differential effects. The effects on the US and USSR are not symmetric.

US-USSR Asymmetry

We want to sketch out here some physical facts and consequences that would affect the USA and USSR in a differential way.

1. The nuclear winter scenario wipes out any advantage the USSR might have because of their megaton weapons. On the contrary, megaton weapons are blunt instruments. They are only marginally more effective against military targets than precisely-aimed sub-megaton weapons held by the USA. But they create much greater environmental impacts. Specifically, weapons with explosive power in excess of one megaton would put particulate material into the stratosphere, thereby producing a longer-lasting climatic effect; they would have a greatly enhanced effect on stratospheric ozone, thereby causing longer-lasting biological problems for the world's population. Finally, they would start fires on a larger scale and over larger areas than an equal number of smaller weapons, thereby contributing more smoke and soot to set off a nuclear winter.

2. To the extent that targets in the USSR are more likely to be snow-covered than U.S. targets, explosions over the USSR

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(3) S. Fred Singer, "The Big Chill"
Wall Street Journal, March 30, 1984

produce less of a nuclear winter effect. The reason is that snow is an effective reflector of the radiation from the fireball so that only a fraction of the energy is available to start conflagrations. Furthermore, the snow must be evaporated before burning starts.

According to the well-known reference The Effects of Nuclear Weapons by Glasstone and Dolan, a one-megaton burst will ignite a variety of materials out to a range of 5 miles (by supplying a heat pulse of 25 calories per square centimeter). With snow reflecting up to 90 percent of the energy, 250 cal/cm^2 must be supplied in order for 25 cal/cm^2 to be absorbed. But the snow must first be evaporated before any ignition can take place; hard-packed snow requires some 700 cal/cm^2 for every centimeter of thickness. Therefore, if the snow layer has a depth of only one inch (2.5 cm), the heat input required is $2.5 \times (700 + 25) \times 10$ or 18125 cal/cm^2. This energy is 725 times greater than the ignition energy required without snow, and would be obtained only within about 1000 ft of the explosion. If the burst occurs at a moderate altitude, there would be no ignition produced on the surface.

3. The Soviet Union has just about one-half the energy consumption of the United States (and even less on a per-capita basis). In general, less fuel storage means less smoke, and therefore a reduced nuclear winter effect if bombs explode over the USSR.

4. The nuclear winter scenario wipes out any Soviet advantage in civil defense. The Russians have invested heavily, we are told, in conventional civil defense which provides protection against blast effects and radioactive fallout. But it does not provide protection against the longer-lasting effects of a nuclear winter. To the extent that Soviet nuclear strategy is based on the belief that their civil defense system will save a large fraction of their population, this thinking now has to be revised or, at least, seriously re-examined.

5. The Soviets have had the traditional geographic advantage of a larger territory. The conventional aftereffects of a nuclear exchange, even radioactive fallout, would be less effective in a larger, more sparsely populated area; the nuclear winter effect, being global (or at least hemispheric), wipes out this geographic advantage.

6. On the contrary, a nuclear winter effect would be more severe in the Soviet Union because of their precarious agricultural base. Without large grain stores and without excess production, the Soviet Union is extremely sensitive to even minor climatic fluctuations. The poor performance of Soviet agriculture is regularly blamed on droughts and other climatic events which are not commonly considered as catastrophic. The United States, on the other hand, would have available not only a reserve base of production which would be effective if the climatic disturbance is not too severe, but also stored

grain. One of the important forms of storage is the beef cattle population which consumes something like 90% of all grain in the United States. In a major climatic disturbance, prices would rise to such an extent that it would become uneconomic to feed grain to cattle; it would be available for human use. The surviving U.S. population, therefore, would not starve but would consume less meat.

7. In the case of a nuclear winter, the climate effect on the Soviet Union is likely to be more severe. Most of the Soviet Union has a continental climate; the major cities are inland, far removed from the moderating influence of the ocean. The Soviet Union has its population much further north than the United States; Moscow is at about the latitude of Labrador. While the U.S. and USSR are likely to have adequate supplies of oil and gas, the distribution to population centers by pipelines is less developed in the USSR; therefore its surviving population would be harder hit by a deep freeze.

Enough has been said to indicate that, all other things being equal, the Soviet Union would be at a serious disadvantage with respect to the United States -- even if the nuclear winter effects are not as severe as indicated in the TTAPS scenario. Of course, much research needs to be done, and this is a fertile field for climate modellers, geographers,

resource analysts, nuclear strategists, and foreign policy experts, not to mention military planners.

Tactical Weapons and Escalation

Turning from strategic nuclear exchanges to the tactical use of nuclear weapons, the accepted wisdom has it that nuclear war necessarily escalates and that therefore the use of nuclear weapons in Europe would lead to a Russian nuclear strike against the United States. But this wisdom needs to be re-examined, particularly in view of the probability that a major nuclear exchange will leave the Russians at a disadvantage, as discussed above.

It is likely that there is no automatic coupling between a defensive use of nuclear weapons in a tactical situation and an offensive first-strike with strategic nuclear missiles. The nuclear winter scenario decouples these two events even further.

Of particular interest is the not yet available "enhanced-radiation" weapon, which by its very design puts most of the energy into penetrating nuclear radiation rather than into the blast and heat effect. As a result, the ER-weapon will produce little radioactive fallout and significantly less fire, smoke, and climate effect. While 100 megatons of strategic nuclear weapons exploded at the right places and altitudes could trigger a nuclear winter according to TTAPS, 100 megatons of ER-weapon air bursts would produce little, if any, climate effect.

Imagine, therefore, the following scenario. The Soviet Union launches a massive attack against Western Europe using conventional weapons and especially their overwhelming superiority in tanks and artillery. The attack is quickly stopped by ER-weapons (if deployed) while the tanks are moving through Eastern Europe. Neither the Soviet Union nor NATO launch attacks on population centers. Would the Russians escalate nuclear warfare and launch an overwhelming missile attack against the United States?

Of course, much depends on the Russian perception of the reality of the nuclear winter scenario. High-ranking Soviet scientists who are well connected with the establishment, such as Yevgeniy Velikhov and Serguei Kapitsa, have participated with American scientists in endorsing the reality of the nuclear winter scenario. The Russian press and television have given much publicity to this scenario. We are told that the Soviet foreign minister and defense minister have been personally briefed. From all indications, the Soviet establishment has embraced the TTAPS scenario, particularly since it appears consistent with their general political aims of achieving a "nuclear freeze". Whether they will continue to embrace it once they become convinced that it leads to disadvantages for them, remains to be seen. Expert Soviet watchers will, no doubt, look for tell-tale signs in the right journals and in statements to the public as well as to

international forums. Soviet scientists may yet disown the nuclear winter scenario which they have just embraced so fervently.

Third World Strategies

Even though we cannot know how Soviet leaders really feel, it is safe to assume that their leadership, like ours, will assign a certain probability to a nuclear winter scenario, and that these probabilities may grow and wane depending upon scientific and political fashions. But it would not be safe to discount the existence of such a scenario entirely.

Similar perceptions will probably circulate in the rest of the world, influenced largely by pronouncements from the major scientific centers, principally the United States. Once accepted, they will cause some re-thinking in the strategies of other nations, particularly the trigger-happy radical regimes.

One can imagine that in their fondest dreams Khomeini or Qaddafi would like to see the U.S. and the USSR finish each other off, together with all of Europe; in the conveniently-created power vacuum the radical Islamic nations could play an important role. There are scenarios extant in which such nations would try to provoke an all-out nuclear war between the superpowers. There are strategists in the U.S. who hope for a Soviet-Chinese knock-out. There must be strategists in China who fervently hope for a nuclear knock-out between the capitalists and Soviet neo-imperialists.

All of this thinking must now be rethought and revised. No longer can non-superpowers get off scot-free in a superpower confrontation. It should give the Third World a powerful incentive to do everything possible not to provoke the superpowers into a nuclear exchange.

As far as the populations of NATO and the East bloc are concerned, a nuclear winter scenario adds only marginally to the general horror of an all-out nuclear war. There is a well-known aria in "The Abduction from the Seraglio" when Osmin Pasha threatens Belmondo: first he'll behead him, then hang him, then burn him, then flail him. After being exposed to megaton blasts, incineration, radioactive fallout, etc., people may not care if the weather turns cold. But to the Third World, dependent on U.S. grain exports and other assistance, a nuclear winter scenario, even a minor one, may spell the difference between life and death.