MTR-7443

LIVING WITH CLIMATIC CHANGE

Phase II

A SUMMARY REPORT FROM A
SYMPOSIUM AND WORKSHOP HELD BY
THE MITRE CORPORATION
McLEAN, VIRGINIA
NOVEMBER 9, 10, AND 11, 1976

Sponsored by
The MITRE Corporation
Aspen Institute for Humanistic Studies
American Meteorological Society

Edited by: Edwin Keitz Dorothy Berks

January 1977
The MITRE Corporation, METREK Division

Approved for public release; distribution unlimited

ABSTRACT

Scientists concur that climate is not a fixed component of our natural environment. However, there is less agreement with regard to when and how climatic change occurs. The symposium, LIVING WITH CLIMATIC CHANGE, PHASE II, opened a dialogue among members of the scientific field and leaders of industry, commerce and government. It explored how climatological instabilities may be met by various industrial sectors within the operative time period of up to 10 years. Areas examined included food and fiber, water, resources, construction, energy, transportation and finance. A summary is given of the major findings and conclusions of the conference.

ACKNOWLEDGMENTS

The editors would like to express their thanks to Dr. Kenneth C. Spengler and the other staff members of the American Meteorological Society for their active participation and assistance in planning and conducting the symposium.

The editors would also like to express their thanks to Dr. Walter Orr Roberts and the staff of the Aspen Institute for their assistance in arranging and supporting the symposium.

A special thanks is also due to the MITRE/METREK staff members who served as coordinators of the six workshops and provided the material for the workshop summaries contained in this document. These staff members are: Dr. Robert G. Henderson (Food and Fiber); Dr. Ali Ghovanlou (Water Resources); James J. Carmichael (Construction); Dr. Edward J. Friedman (Energy); Harry J. Sheetz (Transportation); and Edwin J. Keitz (Finance).

This symposium was planned and supported under MITRE/METREK Internal Research and Development (IR&D) Project 9700/FY 1977. The Project Leader was Edward A. Ward. The period of performance was from July 1976 to December 1976. The editors would like to thank the Project Leader and the IR&D Committee (Herbert D. Benington, Chairman) for their interest, advice and support throughout the development of this report.

FOREWORD

LIVING WITH CLIMATIC CHANGE, PHASE II was held in Reston, Virginia on November 9 through 11, 1976, as the second phase of a continuing North American effort to address the effects of climatic variations on future planning. Sponsored jointly by the MITRE Corporation, the Aspen Institute for Humanistic Studies and the American Meteorological Society, the symposium brought together climatologists, planners and decision makers to explore the potential impacts of climatic instability and fluctuation. The initial conference, LIVING WITH CLIMATIC CHANGE, was held in Toronto, Canada, November 17 through 22, 1975, under the combined auspices of the American Meteorological Society, the Science Council of Canada, the Canadian Meteorological Society, the Geophysical Institute of the National Autonomous University of Mexico and the Mexican Geophysical Union.

After an introductory outline of the background and goals of the symposium by Charles A. Zraket, Senior Vice President of The MITRE Corporation, the symposium plenary session on November 9 was keynoted by Dr. Walter Orr Roberts of the Aspen Institute for Humanistic Studies. Following a series of presentations on climate by members of the scientific community, other speakers presented their views on the impact of climatic change on the industrial sector. Areas of discussion included:

Food and fiber
Water supply and control
Energy supply and distribution
Air, water and land transportation
Construction
Finance

The workshop session on November 10 was divided into six panels: food and fiber, water resources, construction, energy, transportation and finance. The luncheon speaker was Dr. Charles L. Hosler, President of the American Meteorological Society. Panel chairmen presented summary reports on November 11. More than 150 specialists from industry, government and nonprofit/academic institutions participated in the symposium and workshops. The symposium chairman was Dr. Richard S. Greeley, Technical Director of MITRE/METREK Energy, Resources and Environment Division.

Considered historically, climatic data indicate that the Earth is moving into a cooling cycle. However, the impact of human activity in recent times has given rise to controversy covering a full spectrum of climatic possibilities ranging from warming to cooling trends. Among climatologists, the sole point of agreement is that we are entering into a period of increased climatic change and variability.

The PHASE I conference called for planners working within weather-sensitive fields of human endeavor to propose defensive strategies to ameliorate the consequences of weather when detrimental and offensive strategies to capitalize on the consequences when favorable. In response to this mandate, LIVING WITH CLIMATIC CHANGE, PHASE II invited leaders of industry, commerce, government and academia to share their thinking and planning as related to the prospects for significant changes or instabilities in climate within a period of up to 10 years.

As the PHASE II conference progressed an unexpected aspect of the climate of the conference itself emerged. Except on the most abstract, theoretical or philosophical levels, few recommendations were made, few conclusions were reached. Greater emphasis was placed on how climatic change might affect a given sector than upon what plans might be made to meet the challenge of climatic change. A sense of urgency was not communicated. Market mechanisms have not signaled to private industries the need for planning. It was stated by many that government support of research in this critical area has not been substantial. For want of a more predictable data base, future climatic shifts were not considered by industry to be of much importance. These were not the conclusions which had been hoped for at the onset of the conference. However, they present a fair picture of the level of interest and awareness of the moment. We do now feel, however, that had the Conference been held at the end of the long and difficult winter of 1976-1977, more interest and significant progress would have developed.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	vii
LIST OF TABLES	vii
Summary of Major Presentations	1
Climatic Change Effects on Food and Fiber Planning	3
Climatic Change Effects on Water Resources Planning	4
Climatic Change Effects on Construction Planning	5
Climatic Change Effects on Energy Planning	7
Climatic Change Effects on Transportation Planning	8
Climatic Change Effects on Financial Planning	10
APPENDIX: Program of the Symposium	13

LIST OF ILLUSTRATIONS

Figure Number		Page
1	Seventy-Five Year Record of Summer Average Temperature and Rainfall in the Five Major Wheat Producing States of the U.S. (Oklahoma, Kansas, Nebraska, S. Dakota and N. Dakota)	4
2	Categorization of the United States into Six Construction-Industry-Pertinent Climatic Zones	6
3	Atmospheric Concentration of Carbon Dioxide	7
4	Temperature Change Due To Doubling CO_2 Concentration In Air (Data From Manabe)	8

LIST OF TABLES

Table Number		Page
I	Recommended Climatic Elements To Be Observed for Agricultural Purposes	4
II	Economic Impact of Weather on the Construction Industry of the United States (1970 Estimates)	6
III	Percentage of Weather-Created Losses Which Can Be Saved Through Appropriate Use of Weather Information	6
IV	Summary of Annual Dollar and Percentage Losses Due to Adverse Weather in the United States	10
V	Summary, as a Function of Economic Activity, of Potential Annual Savings Due to Operational Improvements, Scientific Advances and Total Gains Due to Improvements in Weather Forecasting in the United States (Figures are in Millions of Dollars)	11

SUMMARY OF MAJOR PRESENTATIONS

During plenary sessions of the symposium, 22 speakers presented viewpoints, programs and recommendations to more than 150 specialists from diverse but interdependent professions. This summary is intended to reflect a cross section of information, opinion, agreement and dissent voiced by the speakers. A complete transcript of the presentations will be published at a later date.

In his opening remarks, Charles A. Zraket, Senior Vice President of The MITRE Corporation described the symposium as part of MITRE's continuing program for bringing together representatives from many fields to review, recognize and implement programs which understand the interrelationships of energy, resources and environment. Mr. Zraket reviewed the findings of the Phase I conference and outlined the need for Phase II to encourage many more international, complementary and cooperative ventures, "especially in the food, energy, resources and environment sectors, since, in most cases, the need is too fragmented, the expense too great and the interrelationships too complex for any one country to undertake major ventures alone." He cited many areas beyond food and water which will be disrupted by climatic instability and stressed the need to design adaptability into our end-use systems.

Keynoting the conference, Dr. Walter Orr Roberts of the Aspen Institute for Humanistic Studies echoed Mr. Zraket's belief in global interdependence. "The margins of tolerable error are narrowing as population stress and technology advance raise the stakes in this climate game." On the other hand, Dr. Roberts stated his belief that sufficient technological capabilities exist to manage Earth's resources for the improvement of the quality of life for Earth's present and future billions. Economic, political and social practices will change, as will value systems and consumption habits. The conference, Dr. Roberts said, was designed to initiate a cooperative search for solutions to problems arising from climatic change and to "find solutions that have human kindness and compassion in them."

Climatologists attending the symposium were in general agreement that the fact of increasing climatic variability is more important than the uncertainty of whether the trend will result in a warmer or a cooler climate.

"We must expect change", said Dr. Charles L. Hosler, President of the American Meteorological Society. "If we are to expect change, we have to design flexibility into our social systems throughout the whole structure." Dr. Hosler expressed his fear that we are not using all we know with respect to meteorology and climatology and that until we come to the point where we can forecast climatic change 10 to 20 years ahead, we must "apply what we know to minimize the risks and hazards and suffering that exist in the world." Higher priority should be placed on promoting broad public understanding of scientific topics so that decision making may be effected on the level of a participatory democracy.

Dr. J. Murray Mitchell of the National Oceanic and Atmospheric Administration observed that what will happen in the future is not necessarily limited to what has happened in the past, since human intervention now presents a possibility that has never existed in the historic or geologic past. Dr. William W. Kellogg and Dr. Stephen H. Schneider, both of the National Center for Atmospheric Research, joined Dr. Mitchell in expressing concern over the increasing concentration in the atmosphere of carbon dioxide from the burning of fossil fuels. Dr. Mitchell observed that we are rapidly approaching a point of critical choice between the continued use of fossil fuels and the development of alternate energy sources. He warned of the dangers of extrapolating from limited experience without adopting a long enough historical perspective.

Dr. Kellogg stated that exponential growth of world population cannot continue, but must level off by the next century. He examined "predictions of a second kind" regarding man's impact on climatic change as related to carbon dioxide, dust, aerosols, fluorocarbons and the heat that we send into the atompshere. He described the implications of a warmer Earth.

Dr. Schneider stated a need for planners to take an international view. Climatic impacts on people are connected to a whole range of social, political and economic interdependence among nations. His personal view is that a 1 percent change in human population, especially one that is preventable, constitutes a crisis and a catastrophe. He agrees with Dr. Kellogg that ultimately there will be a limit to growth of food, population, resources and environment.

"New challenges such as energy and food do not fit into our present institutional framework," said Herbert D. Benington, Vice President of MITRE/METREK. "Energy and food, respectively, present us with some of the most difficult problems facing the country today. These problems range from international to highly local; they involve both the private sector and the public sector; they require the reconciliation of environmental concerns and quality

of life issues with issues of economic growth and well being." There is, he pointed out, an enormous challenge to government which present institutions seem inadequate to meet. He sees a challenge to the new administration to devise new mechanisms for a more coherent and integrated process. Mr. Benington also outlined the advantages of developing good techniques for predicting both short and long-term changes in climate.

Two such projects already under way were described by Prof. Jack C. Thompson of San Jose State University and by William R. Gasser, of the U.S. Department of Agriculture. Prof. Thompson presented the specifics of a research project funded by the NASA Space Science and Application Office which is designed to evaluate the potential economic value of improved weather predictions. In a project composed of USDA, DOD and NOAA personnel, Mr. Gasser reported that the effort is focusing on the need to define best judgments of the probabilities of change in climate, of its variability, of resultant effects on U.S. and world food production and on related areas affecting national policy.

In his analysis of responses to climatic change, Dr. S.F. Singer of the University of Virginia listed insurance, redundancies and storage as three factors in considering time scales in climatic change. He did not think insurance can protect against a large and general shift of climate extending over a number of years. Redundancies in the areas of food and water are more promising. In the case of food, if there should be crop failures, meat consumption will decrease, and farmers will eventually raise grain for human consumption instead of for feed. As for water, the U.S. has a tremendous cushion in the form of waste water which could be reclaimed by using existing technology. Considering storage, Dr. Singer felt the discount rate would not permit storage of major commodities beyond a five to ten-year period. He suggested that the amount of funding for research on climatological prediction should be determined by assessing how much increased probability of forecasting climatic change can reduce the excessive cost of stockpiling.

Stanley A. Changnon, Jr., of the Illinois Water Survey agreed with Dr. Singer that the effect of climatic change on water resources could be handled within the level of existing technology. The issue of water resources may rest solely on economics, institutional arrangements, and choices made by the public. Although the operation and design of most water control structures are tuned to climatic variations, many are inadequate to handle extreme precipitation variations such as those which occurred in the Western U.S. in in the winter of 1976-1977. Problems such as the effect of climatic change on water quality or the point at which hydrologic structures should be altered are dependent upon sufficient funding. Resolution of the issue will relate heavily to public and institutional decisions regarding investments and costs.

In describing the potential effect of climatic change on performance standards in the construction industry, Robert M. Dillon of the Building Research Advisory Board of NAS/NRC, called for better predictive capability. The construction industry translates climatic change into terms of life loads, flood and wave action, water tables, soil movement, expansion and contraction of materials, moisture-induced decay, insect infestation and fire. These are questions of sensitivity that change continually. There are as many as 12,000 individual codes related to weather and climate, but there are no microclimatological standards for buildings. Buildings tend to be site specific, but no data base exists to accommodate climatic change in this area. In Mr. Dillon's opinion, predictive capability would be more beneficial than historical data. Since any large-scale project requires from 2 to 10 years for completion, criteria must be established now to be included in the design mode.

Dr. Frank L. Hassler of the U.S. Department of Transportation summarized his views on the effect of climatic change on transportation as follows:

"Climate affects people in their daily lives, in their choice of location and in the physicial logistics that support that life. Transportation sustains the physical logistics, broadens the options for individual access to greater choice and greatly foreshortens historical times for complex human interactions to take place.....

....The technology of heating has grown with industrial (temperate climate) man, and modern cooling technology may have spread urban/industrial values southward in the last 25 years to an extent that influences even Presidential elections. "Ideal" climate areas of the world will continue to attract large and important migrations. To the extent that world energy supplies remain a limitation, this effect will be magnified. The limiting influence on these movements will be the transport system's competence to support the physical logistics of the resulting societies. Driven above by climate and bound below by earth potentials, he can deliberately alter his logistics by rationalizing his transport processes."

The need for better forecasting and measuring devices was again expressed by Ted J. Davis, Chief of the Rural Operations Review and Support Unit of the World Bank. Mr. Davis described World Bank activity in agricultural and rural development as its largest single sector of lending. The production of food is highly weather sensitive, and nowhere is the

situation more sensitive than in developing countries, where the whole balance of the economy can be upset by a bad harvest arising from flood or drought. At present, historical weather patterns are taken into account when making "risk analysis" to determine the accuracy of cost-benefit ratios. He cited specific emergency relief programs initiated in answer to climate-induced catastrophies and concluded that many future disasters might be averted by more effective forecasting techniques.

Perhaps the strongest reasons for active support of effective climate forecasting were outlined by W. Kenneth Davis, Vice President of Bechtel Power Corp. Mr. Davis contended that there is no evidence in terms credible to industry that climate will change beyond the recent historical fluctuations. His evaluation of the situation is as follows:

"Although climate is important to industry and to our energy supply and demand considerations, potential climate changes are still regarded as scientific curiosities and are not now being incorporated in industrial planning at any level."

"Secondly, the situation will change only when climatologists are able to make specific forecasts of possible climate changes with credible possibilities for specific areas of activities; and only then, if the rate of change is rapid or equal to the comparable change rates in industry or society. This I thought was a most challenging goal, but I am afraid it is a necessary one."

"Thirdly, the relationship between climate and industrial production is not really well understood. We do not know exactly what a particular change in climate will do to a particular requirement for industrial production or energy supply and demand. Considerable work could and should be done to determine the interrelationships. Essentially, no data is available today which quantifies such effects from changes in climate. There is a great body of data which probably could be analyzed to do this, but I have been unable to find any significant efforts to accomplish this particular goal. I do think it would be worthwhile."

Crystalizing the underlying philosophy of the conference, Dr. Harlan Cleveland of the Aspen Institute for Humanistic Studies quoted the Mexican poet, Octavio Paz, who says that world history has become everyone's task. Dr. Cleveland concluded, "It is probably no coincidence that the world has become everyone's task just when the general public has discovered ecology, the science of mutual relations between organisms and their environment."

"A new outlook," he continued, "a new world view is emerging, based on geophysics and the life sciences, the cracking of genetic codes, the study of what goes on inside a cell, the modeling of complex food, climate, population, energy puzzles and has led to enormous popularization of a word which most people didn't have in their vocabulary fifteen years ago—ecology. And thus, the key word for now, parallel to harmony, struggle and relativity in the earlier cosmologies, might well be interdependent; and there emerges an ethic of ecology; a new perception of a series of limits; limits not to growth, but limits to thoughtfulness, to thoughtlessness, to unfairness and to conflict."

CLIMATIC CHANGE EFFECTS ON FOOD AND FIBER

- *Climatic **fluctuations**, not long-range climatic trends, are of the greatest importance to the production of food, fiber and other nondurable goods.*
- *Long-range climatic trends can be accomodated with changes in crop types and varieties and with changes in cropping practices. Consequently, of greatest importance to agricultural planning is the availability of weather and seasonal forecasts up to six months in advance.*
- *More data and more readily available data are required to support research needed to be able to cope with climatic fluctuations. The most critical need for this research is in the short-term climatic period from several weeks to one season or one year.*

The aspect of climate which is of most importance to agricultural and fiber production is the question of climatic fluctuation. An example of such fluctuations in an important agricultural area is shown in Figure 1. The data show summer rainfall and temperature trends over a seventy-five year period in the Midwestern United States wheat belt. An inverse correlation exists between the average temperature and rainfall. This is clearly seen in the dust bowl and high-yield eras and also during the 1902-1908 period. This negative correlation arises from the characteristics of the long-term weather patterns which affect the temperature and rainfall distributions. Periods of hot dry conditions in the midwest are generally produced by persistent southwest flow at high altitudes which brings hot dry air into the area from Northwestern Mexico and Southwestern United States. In contrast, northwesterly winds at high altitudes bring cool Canadian or northwest Pacific air into the area. These conditions enhance the instability mechanism necessary for the production of summer showers and thunderstorms. Thus, climate prediction for the wheat belt is highly dependent on the ability to predict the location and persistence of the long wave flow patterns over the Western United

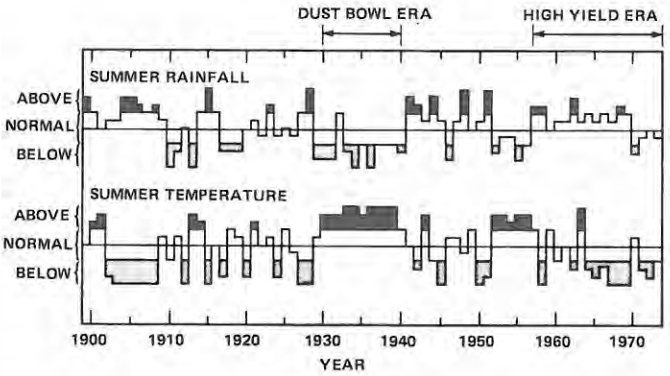

Figure 1
Seventy-Five Year Record of Summer Average Temperature and Rainfall in the Five Major Wheat Producing States of the U.S. (Oklahoma, Kansas, Nebraska, S. Dakota and N. Dakota)

Source: Louis Thompson, Proceedings of Sterling Forest Conference, Dec. 1974, *"World Food Supply in a Changing Climate."*

States. Similar situations can be demonstrated for other agriculturally important areas of the nation. At the present time, predictions of the seasonal or annual behavior of the long wave atmospheric patterns of the Northern Hemisphere cannot be made with any significant degree of confidence.

To compensate for long-range trends and to be able to adjust to climatic fluctuations, a number of research areas must be explored:

- breeding in marginal areas for long range climatic trends
- plant development and its relation to climate
- development of alternate food sources and crops
- continued development of yield prediction models
- development of area dependent cropping practice options
- development of hedging strategies.

To be successful, these research efforts must be supported by a comprehensive and readily available data base. The meteorological data must be collected where it is most relevant, i.e., from agricultural areas. It is proposed that, in the United States, the existing agricultural research stations and extension services be used to gather the necessary data. It is further proposed that the United States attempt to export the concept of extension service in foreign countries. Table I lists the type of climatic data requirements to support the proposed research.

The use of food storage (the so-called Genesis Strategy) as a hedge against severe climatic fluctuations is possible, but is fraught with difficulties. Perhaps chief among them is the problem of locating the storage facilities where they can really be useful in times of need (i.e., in underdeveloped, marginal countries) while maintaining the integrity and security of the facilities. In addition, it is important for domestic, political, and economic reasons that guarantees be made to restrict the distribution of the stored food to extreme emergencies.

Table I
Recommended Climatic Elements To Be Observed for Agricultural Purposes

GROUP	ELEMENT	SUBDIVISION	MACROSCALE *First-order station*	MACROSCALE *Second-order station*	MESO-SCALE	MICRO-SCALE
Thermal elements and their associates	Radiation	Global radiation	X		X	X
		Diffuse radiation				X
		Reflectivity				X
		Sunshine hours	X			X
		Cloud form and cloudiness	X			X
		Terrestrial radiation				X
		Effective outgoing radiation				X
		Net radiation	X		X	X
		Emissivity*				X
		Heating coefficient*				X
		Radiation-distribution within the canopy				X
		Net radiation distribution within the canopy				X
	Temperature	Air temperature	X	X	X	X
		Soil temperature	X		X	X
		Leaf temperature				X
Moisture elements and their associates	Precipitation	Rain	X	X	X	X
		Snow	X	X	X	X
		Hail	X			
		Dew	X			X
		Fog	X			
	Humidity	Humidity	X	X	X	X
	Evaporation	Potential evapotranspiration				X
		Actual evapotranspiration				X
		Pan evaporation	X		X	X
	Soil moisture	Soil moisture storage capacity			X	X
		Depletion rate				X
Advective elements	Pressure	Pressure	X			
	Wind	Upper air wind	X			
		Surface wind	X		X	X
		Wind profile				X
		Roughness*				X

*derived elements

Source: Jen-Ha Chang, "Climate and Agriculture," Aldine Publishing Company, Chicago, IL, 1968.

CLIMATIC CHANGE EFFECTS ON WATER RESOURCES PLANNING

In water resources management, most systems are planned and operated for useful time spans of from one to several decades. Since there is no reason for optimism about potential improvements in forecasting climatic trends for these time periods, water resources planning will continue to rely on past climatic data.

Most systems are planned and operated with a considerable amount of buffering to account for political, sociological, economic, hydrological and climatological uncertainties. Resiliency, however, becomes critical for the systems which are operating near capacity.

For a more efficient planning and management of water resources, the climatic information should be utilized in the following tasks:

- *Development of water basin specific climatic information from the past records.*
- *Modeling of the water resources systems for climatic scenarios to establish operational policies.*
- *More effective utilization of the information on the chemical quality of the precipitation.*
- *Forecasting of climatic modifications adjacent to large metropolitan areas, and determination of operational characteristics of water resource systems in these areas.*

Development of Water Basin Specific Climatic Information

Development of water basin specific climatic information from past records should contain (1) the spatial and temporal frequency distribution of specified events like droughts and (2) extreme event magnitudes. This information will improve the reliability of the resource planning by using actual data instead of assumptions on changes in the climatic parameters. This improvement will be reflected in design and operational planning processes. The need for such information is most crucial in areas of dense population, low rainfall and high food production where the resiliency of the water systems becomes critical, since water resource systems are placed under stress with a greater frequency under such conditions.

Modeling of the Water Resources System

The water resources system, comprising both surface and underground water, should be modeled for climatic scenarios statistically derived from existing climatic data, as well as for alternative scenarios embodying potential climatic changes. The model should be used to establish operational policies for all scenarios and red-light signals (for example, the critical levels of reservoirs and ground water in aquifers) to indicate that the system is moving from a formerly experienced operational mode to a different mode and that a change in management policy is needed. The contribution of the climatologist to basin or regional water resources planning should be to specify for selected basins the climatic parameters needed for the alternative scenarios.

Many water systems are designed for lifetimes of 50 to 100 years. Such lifetimes are long enough for the consideration of significant climatic changes possibly to be induced by human activities like fossil fuel utilization (which may lead to significant shift of storm tracks by hundreds of miles). Although the implications of these scenarios are debated, their potential significance to human affairs is great enough to warrant study of their expected effects on water systems and the changes in operation of these systems that would minimize ill effects.

Quality of Precipitation

Large concentrations of selected chemical compounds introduced by precipitation during low flow periods of a water supply system can create very real health hazards. Advance notice of such events or the possibility of their occurrence gives the water planner the opportunity to prevent or mitigate potentially dangerous situations.

Climatic Modifications Adjacent to Large Metropolitan Areas

Sufficient studies exist of the climatic modifications adjacent to large metropolitan areas (such as St. Louis) to be able to state, in a qualitative sense, whether such modifications can be expected near other large urban centers. The nature and magnitude of such changes must be examined in adequate detail to determine the causative factors and their impacts so that the consequences of future climatic modifications may be forecast with reasonable certainty. These forecasts may be of such magnitude as to influence the operational characteristics of water resource systems and motivate water planners to reexamine their design assumptions.

CLIMATIC CHANGE EFFECTS ON CONSTRUCTION PLANNING

Five inferences were drawn from the evidence presented during the workshop discussions:

- *Better use of available data in the construction industry offers an opportunity for cost reductions comparable to those which improved predictions could provide.*
- *Site specific and/or microclimate projections coupled with more definitive or task specific analyses offer an attractive avenue for productive interaction between climatologists and the construction industry.*
- *There exist major social and institutional impediments to the fine tuning of construction, particularly design, to more precise and reliable climate projections.*
- *The built-in tolerance of construction design and execution practices to short-range weather variability gives them a built-in adaptability to many of the projected long-range trends in climate, particularly in view of the other factors which limit planning horizons to, at the most, a few decades.*
- *The greatest problems which are foreseen are not those arising out of a requirement to*

cope with climatic change, but rather those which may arise as man attempts construction in now sparsely developed parts of the world, especially in those areas where experience data is lacking or where the environmental conditions fluctuate over wide ranges.

The construction industry has been forced to live with the vagaries of the weather since its inception. This is true with respect to the day-to-day variations as well as the geographical differences. Because of this, the potential impacts of gradual climatic changes are seen as minimal. Techniques have already been developed for construction activities in polar regions as well as in tropical jungles. Contingency factors are part of any cost bid package in order to minimize economic risk.

In terms of economic benefit, improved weather forecasting—or improved utilization of the existing capability—is perceived to be more important to the industry than climatic changes. Table II indicates the estimated impact of weather on the construction industry in 1970. It can be seen that intermittent

Table II
Economic Impact of Weather on the Construction Industry of the United States (1970 Estimates)

	Million $	Percent of Specific Cost
Seasonal Impact		
Seasonal Unemployment		
Lost Wages	(1) 1,800	5.2
Unemployment Compensation	312***	
Idle Equipment	(2) 1,000	12.5
Decreased Construction Volume (Highly Speculative)	(3) 12,820	10.6
Additional Heating, Protection	(4) 120	0.5
Total Seasonal	2,920*-13,940**	2.4-11.5
Intermittent Adverse Weather	2,418	2.0
Totals	5,338 -16,358	4.4-13.5

*Includes (1), (2), and (4).
**Includes (2), (3), and (4). (1) is excludes since it is a part of (3).
***Not included in total losses, already accounted for in (1).

Source: Russo, John A. Jr., "The Complete Money Saving Guide to Weather for Contractors," p. 68, Environmental Information Associates, Newington, CT 06111

adverse weather has a greater impact than the seasonal variations. Table III indicates the saving which might accrue due to improved, or better utilized weather predictions, when separated into types of construction and climatic zones. Figure 2 shows the

Table III
Percentage of Weather-Created Losses Which Can Be Saved Through Appropriate Use of Weather Information

	Climatic Zone					
	1 Cold Wet	2 Cold Dry	3 Mild Wet	4 Mild Dry	5 Hot Wet	6 Hot Dry
Construction Segment	10-25%	9-23%	8-22%	7-20%	6-15%	5-10%
1. Residential Construction	10	9	8	8	7	5
2. General Building	20	10	10	9	8	6
3. Heavy and Specialized Construction	25	15	10	9	8	7
4. Highway Construction	25	22	22	20	15	10
5. Surveying	10	9	9	9	8	8
6. Site Grading and Excavation	20	15	12	10	9	8
7. Pile Driving and Dredging	20	15	12	10	8	5
8. Concrete Manufacture and Delivery	25	22	20	18	14	10
9. Carpentry	10	9	8	7	6	5
10. Masonry	25	22	20	15	12	10
11. Roofing	25	22	20	16	12	10
12. Plumbing	10	9	8	7	6	5
13. Bituminous - Manufacture and Delivery	25	22	20	18	12	10
14. Painting	20	15	12	11	11	10
15. Landscaping	25	13	12	11	10	8
16. Paving	25	22	15	13	12	10

Source: Russo, op. cit., p. 85.

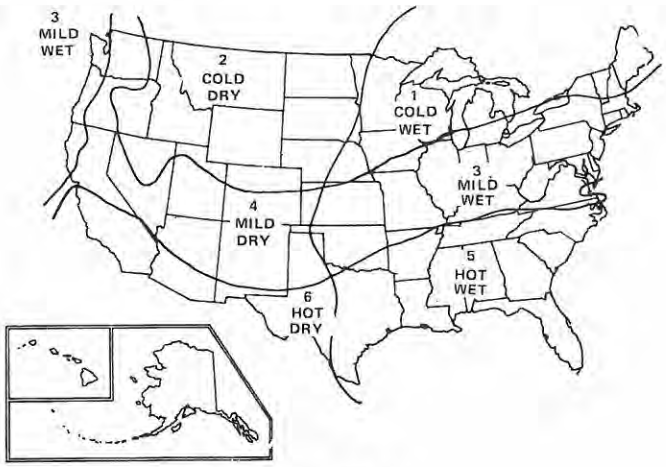

Figure 2
Categorization of the United States into Six Construction-Industry-Pertinent Climatic Zones

Source: Russo, op. cit., p. 7.

geographic distribution of the zones used. It must be stressed that the maximum amount of savings would be a fraction of 1 percent of annual gross receipts of the construction industry. One reason for this misleadingly small percentage improvement is the widespread use, within the industry, of persistence as a weather prediction technique. This is not a particularly bad method when applied to short time frames. The other major reason is the improved methods and materials which have been developed specifically to minimize the effects of adverse weather.

In noneconomic terms, no impact was identified on what gets built, how it is built, or how long the con-

struction lasts. This is due to the same factors mentioned above, namely, the built-in tolerance of the industry to weather variations and the already developed construction techniques for polar and tropical climates.

CLIMATIC CHANGE EFFECTS ON ENERGY PLANNING

Five recommendations were made by the Energy Planning panel on future needs associated with this issue:

- *An improved understanding of the complexities of the carbon cycle, particularly with respect to the relationship between atmospheric and oceanic carbon dioxide concentrations from both anthropogenic and natural sources.*
- *More realistic climatic models which can be used with confidence.*
- *Increased measurement of appropriate climatic features such as sea ice and glaciers. This includes increased utilization of the newer techniques of remote sensing.*
- *Determination of the role of particulate emissions in climatic change.*
- *Determination of the social, economic and political consequences of attempts to stabilize climate by restricting human activities such as consumption of fossil fuels.*

At least three possible interactions have been identified to show an influence of energy activity on climate and its variability. These are:

- production of carbon dioxide as a product of the combustion of carbon-based fuels,
- emission into the atmosphere of particulate matter during the combustion of carbon-based fuels, and
- release of heat into the environment as a result of energy conversion processes.

Because these influences are for the most part poorly understood, their identification in no way specifies their particular impact on global or local climate.

The relationship between climate and human energy utilization is both complex and mutually influential. It is clear that energy consumption depends greatly on vagaries of climate, both in space and time. The influence of energy utilization on climate is not well understood and this lack of understanding is the major impediment to both our ability to plan future energy conversion strategies and our ability to predict the possible influences of our actions.

Under the present conditions of uncertainty in climate prediction, there is great reluctance to utilize climatic forecasts. Furthermore, the potential costs of attempting to adapt to a predicted threat from the energy conversion will be very large. Therefore, confidence in the predictions must be large.

Recent research with numerical models of the atmosphere suggests that the increase of carbon dioxide may have direct and long-standing influences on climate. Figure 3 illustrates the recent rise in carbon dioxide concentrations in the atmosphere at various latitudes. The global aspect of the increase can be seen along with the yearly cycle associated with wintertime use of fossil fuel for heating. About 54 percent of the carbon dioxide produced from fossil fuels is accounted for in the atmospheric increases shown. The record from 1959 through 1974 shows considerable variation in the fraction of produced CO_2 that remains in the atmosphere with a slight tendency toward larger fractions remaining airborne in the later years. These year-to-year fluctuations in airborne fraction indicate that the effectiveness of natural reservoirs (which exchange carbon dioxide with the atmosphere) fluctuates as other conditions change—quality and length of growing season, for example, or abnormal temperatures and currents in upper layers of the ocean.

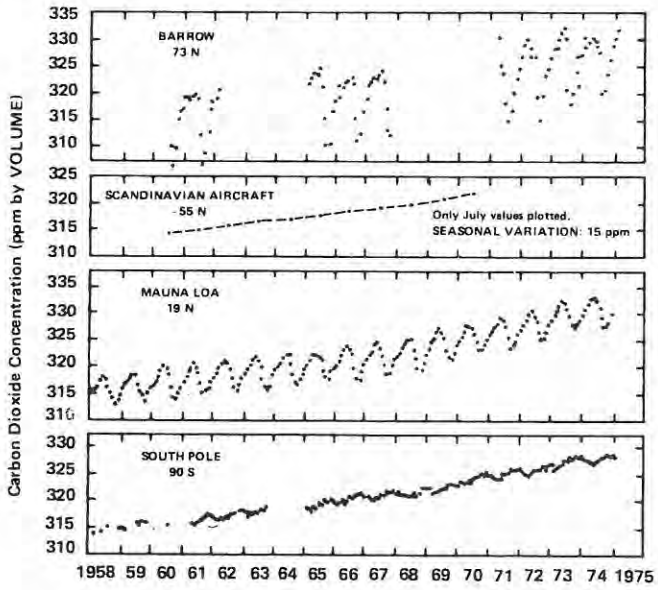

Figure 3
Atmospheric Concentration Of Carbon Dioxide

Source: "The National Climate Program Act," Hearings before the Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology, U.S. House of Representatives, Ninety-Fourth Congress, Second Session, p. 116.

The possible implications of this trend for world temperatures is illustrated in Figure 4 which shows data resulting from a climate model. A doubling of the

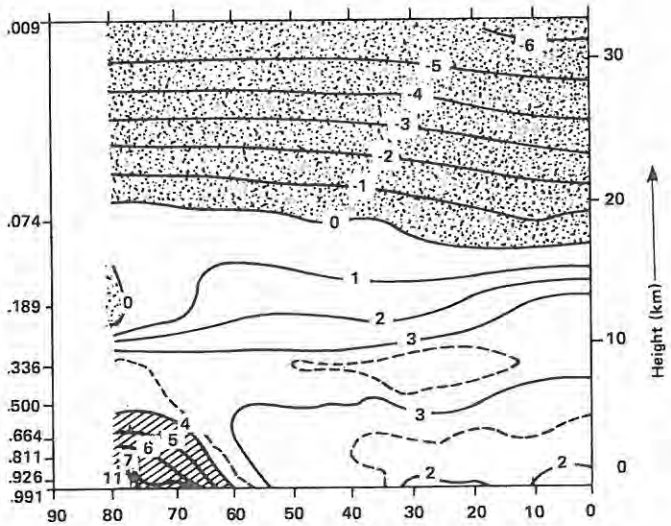

Figure 4
Temperature Change Due To Doubling CO_2 Concentration In Air (Data From Manabe)

Source: "The National Climate Program Act," Hearings, op. cit., p. 119.

current levels of carbon dioxide has been assumed in the model but feedback mechanisms such as clouds and atmosphere-ocean interactions are neglected. The cooling of the stratosphere and especially the pronounced warming near the surface in higher latitudes are highly significant. The effects of warming the earth's surface north of 70° N by more than 7° Kelvin will be extreme. The model shows that the sea ice would retreat and the warming effect in this region would be reinforced because open water absorbs more of the incoming solar radiation than ice does.

The part of the problem which can be discussed with most confidence is the probable future uses of fossil fuels. What is less certain is the long-term magnitude of the influence. This uncertainty is vexing from several points of view. First, the implications of our current action may be very severe. Second, a course of action needed to avoid the possible disasterous results may require decision making within the near future (10 years or so). Third, the international aspects of both the cause and effect of the problem demand an immediate and continuous attack on the problem which can assist in global decision making on issues such as the use of alternative fuel systems (i.e., nuclear or solar power).

This particular example of the relationship between energy conversion and climate illustrates the typical problems which may be encountered. In summary, they are:

- Imprecise identification of cause and effect relationships.
- Nonquantitative prediction of future climate due to both natural and antropogenic influences.
- The inability of current social and political institutions to base their long-range planning on imprecise predictions of future conditions.
- The general inflexibility of our energy production facilities to possible changes which may be required by predictions of future climate.

It is within this set of somewhat uncertain conditions that decisions must be made. It is recognized that a need for new societal mechanisms exists for both fostering the research needed as well as accepting and acting upon the recommendations which come forth from the scientific community.

CLIMATIC CHANGE EFFECTS ON TRANSPORTATION PLANNING

The United States transportation system has enough excess capacity and mode diversity to be able to cope with near-term climatic variations. The time scale of major changes in the transportation system is short (about five to ten years) compared to the time constant of long-term major climatic variables that might affect the capabilities of an individual transportation mode.

Transportation depends almost exclusively on hydrocarbon fuels and will be the most difficult energy consuming sector to draw away from the utilization of hydrocarbons.

Specific modes of transportation are effected by climatic change as follows:

- *If a climatological shift from normal significantly exceeds design expectations, failures within the aviation system could lower the level of aviation safety.*
- *A one to two-month climatic prediction is desirable for marine transportation particularly for expected ice conditions.*
- *Research and development should be undertaken to determine how much reduction there should be in the dependence of transportation on petroleum products which are contributing excessively to the CO_2 levels. Alternative transportation modes and fuels should be examined from the point of view of their climatic impacts in addition to the energy and environmental effects.*

The Transportation Panel divided its concern into three time periods: the near-term (up to approximately two weeks), a five- to ten-year time period and until the end of the century. It was concluded that the

United States transportation system has enough excess capacity and mode diversity to be able to cope with near-term climatic variations. For example, there are 10,000 airports, 10,000 miles of inland or coastal waterways, 200,000 miles of railroad and 3,000,000 miles of roads in the United States. When one mode is adversely affected by climatic variation, another mode can be and is selected with, of course, some minor delays.

The time scale of major changes in the transportation system is short (about 5 to 10 years) compared to the time constant of long-term major climatic variables that might affect the capabilities of an individual transportation mode. In the long-term, we tend to fear human inconsistencies as well as tempests due to climate. Specifically, the concern over atmospheric CO_2 could lead nontechnical decision makers prematurely and perhaps unnecessarily to limit transportation CO_2 emissions causing damage to the nation's transportation system.

It is possible to heat homes with solar or nuclear electric energy but possibly at some additional costs. However, a nuclear or solar-powered aircraft, automobile or truck is not a feasible option at this time. Battery-powered or hydrogen-fueled highway transportation may remain impractical for some time. Transportation depends almost exclusively on hydrocarbon fuels and will be the most difficult energy-consuming sector to draw away from the utilization of hydrocarbons.

Air Transportation

One of the prime concerns of air transportation is the safety of flight which is directly dependent upon accurate and timely information on weather conditions at all points along the flight path. If there is a climatological shift from normal climatic conditions that significantly exceeds design expectations, failures within the aviation system could lower the level of aviation safety. If the direction and duration of a shift in climatological conditions were known, adjustments in the design of the air transportation system could be made in anticipation of rather than in reaction to the need.

Several issues relate to climate and air transportation:

- *The impact of high altitude flights upon the ozone layer.*
- *Improved methods of predicting both surface and high altitude air turbulence.*
- *The impact of a severe winter on the cost of fuel, thereby directly affecting the profitability of commercial air carriers and the higher cost of fuel for military aircraft.*
- *Weather modification systems such as fog dispersement on runways which would reduce traffic delays and improve safety.*

Marine Transportation

The oceans and seas cover over three-fourths of the earth's surface, and approximately 90 percent of the total population of the world lives along the margins of seas. Marine transportation is a primary source of goods shipment and of the resupply of nations experiencing natural disasters such as crop failures due to weather conditions.

The cost effectiveness of marine movement of cargo and goods is highly dependent on the availability and usage of information on climatic changes and ice conditions expected on the seas, rivers, and lakes. The northeastern portion of the United States is most affected by formation and distribution of lake and river ice, although a particularly harsh winter may have a severe impact on extended inland U.S. waterways and therefore on shipments of foreign exports and imports from or to inland rivers, lakes and bays. For example, many oil refineries, located on inland waterways, are supplied by foreign oil tankers. Without the constant supply of oil for industry and residential use, a crisis might occur causing industrial shutdowns and increase oil and gasoline prices, thereby affecting the economy. Extensive environmental impacts may also occur if the huge oil tankers or barges were to get locked into ice, fracturing the ship's hull and resulting in an oil spill. If the benefits justify the additional cost, it may be possible to maintain year round navigation by alteration of some waterway systems. For example, if the St. Lawrence shipping period could be extended 15 weeks, it is estimated that it would reap a benefit of $800 million. Inland waterways external to the ice bound areas are minimally affected by a changing climate. The phenomena which would alter transportation plans is considered to be flooding caused from ice and snow melt and also excessive rainfall. To plan for these problems, a one to two-month climate prediction is desirable.

Ground Transportation

Most of all manufactured commodities that flow through the United States transportation network are by some form of ground transportation. In 1972, the dollar value of these commodities exceeded $440 billion at wholesale prices. If, for example, there were just a one hour delay in every one hundred, the value lost would be over $180 million. This does not include losses owing to accidents. In one study of 24,000 accidents in the last half of 1973, an attempt was made to correlate the number of deaths with specific weather conditions at the accident site. The correla-

tion was poor, but it seemed to indicate that weather contributes to perhaps as much as 7 percent of the total fatalities or about 2,700 fatalities per year. Assuming the Department of Transportation's values for loss of life and injury, weather impacts on safety in auto travel may exceed $740 million annually.

Some studies have indicated a relationship between CO_2 levels and weather. About 25 percent of the present CO_2 level is caused by transportation burning of petroleum with the largest contribution from urban automobiles. The CO_2 levels on a global basis are mainly attributed to the United States, Russia and Europe, with each of these regions contributing about 20 percent. The equivalent fraction of the atmosphere of CO_2 is 2 to 3 ppm. Future predictions of about 6 to 7 ppm are quoted for the year 2000. With the rate of 6 ppm/yr (12,750 x 10^6 mT carbon) and half of the CO_2 remaining airborne, 380 ppm are expected for the year 2000. This increase can be expected to cause 0.5°C global average surface temperature increase. Research and development should be undertaken to determine if we should reduce the dependence of transportation on petroleum products which are contributing excessively to the CO_2 levels. Alternative transportation modes and fuels should be examined from the point of view of their climatic impacts in addition to their effects on energy and environment.

CLIMATIC CHANGE EFFECTS ON FINANCIAL PLANNING

Various segments of the industry are affected in differing ways by short-term climatic change:

- *The insurance industry would be affected by changes in the occurrence of severe climatic events resulting in an altered income potential.*
- *The banking industry would be affected principally through crop failures and subsequent inability to repay farm loans.*
- *The investment industry is required to provide capital for redundancy in many industries in order to insure continued operation during adverse climate events.*
- *The commodities industry automatically adjusts to all major events by price fluctuation in the market place.*

In general the financial industry is not structured to respond to forecasts of future events. Very high probabilities of occurrence would have to be assured before any action would be contemplated.

The potential dollar value associated with a given change in climate is difficult to determine. However, insight into the magnitude of this potential may be gained by considering the annual losses incurred in various activities due to adverse weather. A summary of these losses is shown in Table IV. The potential annual savings due to improvements in weather forecasting only are shown in Table V. Agriculture dominates in both the annual losses and potential savings.

Table IV

Summary of Annual Dollar and Percentage Losses Due to Adverse Weather in the United States.[1]

	Total losses, irrespective of whether or not protective measures could be taken against adverse weather.		Losses due to adverse weather which could be protected against if adequate warnings for appropriate period in advance could be provided.	
Activity	($ x 10^6)	(%)	($ x 10^6)	(%)
Agriculture	8,240.4	(15.5)	3,554.2	(6.7)
Aviation (commercial)	92.4	(1.1)	56.9	(0.7)
Construction	998.0	(1.0)	328.6	(0.3)
Communications	77.4	(0.3)	6.4	(0.1)
Electric Power	45.7	(0.2)	13.9	(0.1)
Energy (e.g., fossil) Fuels	5.1	(0.1)	1.0	(0.1)
Manufacturing	597.7	(0.2)	238.0	(0.1)
Transportation (rail, highway & water).	96.3	(0.3)	45.8	(0.2)
Other (gen. public, government, etc.)	2,531.8	(2.0)	1,057.8	(0.9)
Totals	12,684.8		5,302.6	

[1]Figures are overall losses for each activity, and (in parentheses) percent of annual gross revenue. This data presented by Jack Thompson

The insurance industry incurred weather-associated losses of $9.2 billion during the period 1949-1975. Any change in the frequency of occurrence of these losses would cause a significant change in the total without a corresponding adjustment in premiums paid. The principal segment of the industry affected by climate change would be property insurance. Life insurance would be unaffected and auto insurance affected only to a minor extent.

The banking industry would be affected by climate change principally through its impact on agriculture.

Table V
Summary, as a Function of Economic Activity, of Potential Annual Savings Due to Operational Improvements, Scientific Advances and Total Gains Due to Improvements in Weather Forecasting in the United States. Figures are in Millions of Dollars.**

Activity	Operational Improvements	Scientific Advances	Total Gains*
Agriculture	250.3	316.7	567.0
Aviation (commercial)	1.4	2.2	3.6
Construction	13.1	18.4	31.5
Communications	0.3	0.4	0.6
Electric Power	0.5	0.8	1.3
Energy (e.g., fossil) Fuels	#	0.1	0.1
Manufacturing	8.1	11.9	20.0
Transportation (rail, highway & water)	1.3	1.9	3.2
Other (gen. public, government, etc.)	47.3	64.5	111.8
Totals*	322.2	416.9	739.1

* All sums may not balance due to rounding off.
\# Less than 0.05.
** Data presented by Jack Thompson

Many banks have major portions of their assets invested in farm loans. The ability to repay such loans is highly dependent on crop successes or failures.

The investment industry is required to provide substantial amounts of capital to many industries for the provision of redundant systems. The need for this redundancy arises in part from adverse weather and potential short-term climate fluctuations. A prime example of such a highly redundant system is the AT&T communications network.

The commodities (food) industry has the capability to react on a relatively short-term basis (one to two years) to climate fluctuations. These reactions may include any of the following approaches, each of which has specific financial impacts:

- *Geographical diversity—growing the same crop in widely scattered locations.*
- *Geographical displacement—moving location of specific crops to favorable areas.*
- *Crop selection—planting crops favorable to the changed climate.*
- *Development of new species—drought or temperature-resistant strains.*
- *Elimination of meat cushion—feeding grain directly to humans rather than to livestock.*

APPENDIX: Program of the Symposium

Tuesday, November 9

		Speakers
8:00—9:00 a.m.	Registration	
9:00 a.m.	Plenary Session	
	Symposium Chairman: Dr. R.S. Greeley—MITRE/METREK Division	
	Introductory Remarks	C.A. Zraket, The MITRE Corporation
	"Living with Climatic Change"	Dr. Walter Orr Roberts, Aspen Institute for Humanistic Studies
	"Record of the Past, Lessons for the Future"	Dr. J. Murray Mitchell, National Oceanic & Atmospheric Adm.
	"Human Influence on Near-Term Climate"	Dr. W.W. Kellogg, National Center for Atmospheric Research
	"The Response to Climatic Change: The Significance of Different Time Scales"	Dr. S.F. Singer, University of Virginia
12:00—1:30 p.m.	LUNCHEON—"What Climatologists Can Say to Planners"	Dr. S.H. Schneider, National Center for Atmospheric Research
1:30—5:00 p.m.	"National Security and Climate Relationships"	Herbert D. Benington, MITRE/METREK Division
	"Economic Value of Improved Long Range Weather Forecasts—Some Implications for Predictions of Climatic Change"	Professor Jack C. Thompson, San Jose State University
	"World Climatic Changes and Agriculture—The Issues"	William R. Gasser, U.S. Department of Agriculture
	"Water Resources and Climate"	Stanley A. Changnon, Jr., Illinois State Water Survey
	"Energy and Climate"	W. Kenneth Davis, Vice President, Bechtel Power Corporation
	"Transportation and Climate"	Dr. Frank L. Hassler, U.S. Department of Transportation
	"Performance Standards in Relation to Climatic Change in Construction"	Robert M. Dillon, Building Research Advisory Board, NAS/NRC
5:30 p.m.	COCKTAILS	
6:30 p.m.	DINNER — "The Climate for a New World Order"	Dr. Harlan Cleveland, Aspen Institute for Humanistic Studies

Wednesday, November 10

		Workshop Chairmen
9:00 a.m.	Panel Workshop Sessions	
	• Workshop Panel I "Climatic Change Effects on Financial Planning"	Dr. S.F. Singer, University of Virginia
	• Workshop Panel II "Climatic Change Effects on Construction Planning"	Dr. M.R. Gustavson, Lawrence Livermore Laboratories
	• Workshop Panel III "Climatic Change Effects on Transportation Planning"	Dr. Lawrence A. Goldmuntz, Economics & Science Planning
	• Workshop Panel IV "Climatic Change Effects on Energy Planning"	Dr. Thomas F. Malone, Butler University
	• Workshop Panel V "Climatic Change Effects on Water Planning"	Dr. E.G. Walther, Charles F. Kettering Foundation
	• Workshop Panel VI "Climatic Change Effects on Planning for Food and Fiber"	Dr. Helmut E. Landsberg, University of Maryland
12:00—1:30 p.m.	LUNCHEON—"The Role of Meteorology and Climatology in Decision Making"	Dr. Charles L. Hosler, President, American Meteorological Society

1:30—5:00 p.m.	**Panel Workshop Sessions**	
	(The afternoon workshops will be the same as the morning sessions)	
5:30 p.m.	COCKTAILS	
6:30 p.m.	DINNER—"World Bank Policy and Rural Development"	Theodore J. Davis World Bank

Thursday, November 11

		Workshop Chairmen
9:00 a.m.	**Plenary Session**	
	Workshop Team I Report	Dr. S.F. Singer
	Workshop Team II Report	Dr. M.R. Gustavson
	Workshop Team III Report	Dr. Lawrence A. Goldmuntz
	Workshop Team IV Report	Dr. Thomas F. Malone
	Workshop Team V Report	Dr. E. G. Walther
	Workshop Team VI Report	Dr. Helmut E. Landsberg
	Concluding Remarks	**Symposium Chairman** Dr. Richard S. Greeley

(Working luncheon will be served during this Plenary Session).

WORKSHOP SPEAKERS ON NOVEMBER 10

Speaker	Title	Workshop
Dr. Michael H. Glantz National Center for Atmospheric Research	"Social Value of a Climatic Forecast"	I, II, III, V, VI
Dr. Kenneth B. McAfee Bell Laboratories	"Chemical Change & Transport in the Atmosphere of Eastern U.S."	II
Peter J. Schreuder Geraghty & Miller, Inc.	"Climatic Change and Ground Water Utilization"	I, V
Dr. Aaron Wiener Tahal Consulting Eng'rs., Ltd.	"Water Resource Planning in Arid Areas"	I, V
Gordon Barnes Barnes Weather Service	"Application of Long-Range Forecasting & Decision Making"	III, VI
Dr. Joseph Haun Clemson University	"Quantification of Plant-Environmental Relationships"	VI