NOAA Program Plan 71-1

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Plans and Programs

Geophysical Monitoring for Climatic Change

Atmospheric Division

ROCKVILLE, MD.

February 1971

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GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE

Atmospheric Division

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FOREWORD

This Plan for Geophysical Monitoring for Climatic Change is the National Oceanic and Atmospheric Administration (NOAA) program for global monitoring of man's inadvertent modification of weather and climate. The interrelated activities, several of which should be conducted simultaneously, are analyzed in terms of the requirements and the actions to be undertaken.

The program is an expansion of NOAA's present capabilities for baseline monitoring of ocean and atmospheric properties, constituents, and contaminants likely to influence climatic change; and will be enlarged to a global basis through international cooperation, where possible. The ultimate objective is to gain sufficient data and knowledge to predict climatic change resulting from man's activities.

The Plan includes the cost estimate of achieving the programmed goals over five phases, each approximating a fiscal year. The Plan calls for early establishment and operation of the global baseline monitoring system. However, the major areas of effort are sufficiently flexible to allow priority consideration of the needs of the Council on Environmental Quality, the Environmental Protection Agency, and others active in monitoring and improving the natural environment of the Nation.

Robert M. White

Robert M. White, Acting Administrator
National Oceanic and Atmospheric
Administration

GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE

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GEOPHYSICAL MONITORING FOR CLIMATIC CHANGE

INTRODUCTION

It has been readily recognized worldwide that one of the primary building blocks for environment management is a comprehensive knowledge of man's impact on the natural weather and climate. Man's technological explosion has now reached the stage where the effluents of society may be sufficient in amount and kind to bring about inadvertent changes in global climate. In addition, natural occurrences such as large volcanic eruptions may inject huge quantities of dust and gases into the atmosphere and also may cause changes in the amount of received solar radiation, precipitation nuclei, and possibly other important parameters. Determination of the trends of the climatically important burden of atmospheric contaminants and resolution into natural versus man-induced source is essential to the preservation of environmental quality.

Considering the scope and complexity of the problem, there are basic questions that must be answered in the immediate future if timely worldwide corrective measures are to be taken. Is there an increasing carbon-dioxide-induced "greenhouse" effect, with a warming of the earth's surface and a resultant decrease in polar ice? Conversely, is there the increase in atmospheric contaminants and cloud-producing condensation nuclei that will reduce incoming solar radiation by the small 1.0 to 1.5 percent sufficient for the start of glaciation and development of ice cover reaching into temperate latitudes? As of the present time, there is no creditable evaluation of the extent to which man is inducing a climatic catastrophe, however, there is little doubt that the stake in terms of human welfare, if not survival, is so high that the relatively small investment for monitoring, research, and prediction must be made.

The January 9, 1969, Report of the Commission on Marine Science, Engineering and Resources (Stratton Commission Report) documented the need for accelerated understanding of oceanic and atmospheric processes as a prerequisite to improving the assessment and control of man's pollution of the environment. The commission also recommended that the National Oceanic and Atmospheric Administration (NOAA) initiate and lead an intensive national program to explore global environment monitoring and to investigate the feasibility and consequences of its modification. The August 1970 Annual Report of the Council on Environmental Quality (Train Report) stressed that worldwide recognition should be given to the long-term significance of manmade atmospheric alterations, and that research on models of the ocean-atmosphere physical system needs emphasis. Predecessor agencies of NOAA have maintained an active study of this problem for the past several years, have been engaged in all aspects of climatology, have operated the only locations in the world devoted to clean air observation at Mauna Loa, Hawaii, and in the Antarctic, and have reviewed and contributed to the conclusions and recommendations by appropriate governmental agencies and by and throughout the national and international scientific community. This NOAA Plan will launch the global geophysical monitoring system.

I. OBJECTIVES

The objectives of the geophysical monitoring for climatic change program are:

- To monitor the geographical and altitude distributions and long-term trends of air composition and the properties for pollutants of manmade and natural origin.
- To monitor oceanic constituents, properties, and processes likely to influence climatic change.
- To predict changes in climate resulting from man's activities. (This will also take into consideration changes resulting from natural phenomena.

II. PROGRAMS

Several interrelated programs must be conducted simultaneously to obtain the necessary baseline data, provide the subsequent observations and sampling for change determination, understand the mechanisms causing alterations in atmospheric constituents and properties, and determine the current and predict the future nature and extent of change in the climate of the world resulting from man's activity. An analysis of these requirements and the planned program for each are set forth in the following sections.

A. Data Acquisition and Monitoring

1. Global Baseline Land Station Monitoring

a. Requirements

Monitoring is needed for those long-term global trends in atmospheric constituents and properties likely to produce climatic change, A system for measurement of the long-term burden of atmospheric trace contaminants does not now exist in the quantity or with the accuracy required to determine either the historical trend of such material or its possible climatic effects. Adequate records are not available to determine the trend of particulates; only one known station (Mauna Loa) has collected satisfactory clean air data of atmospheric carbon dioxide which may be used in determining the growth of this pollutant in the atmosphere. The limited Mauna Loa record covers only the last 12 years and has not exhibited a constant growth rate. However, there has been a threefold increase in the growth rate of atmospheric carbon dioxide during this period. How representative this increase may be of the clean air part for the rest of the world can be determined only with additional new baseline stations that should also provide clues as to the cause of the changes in carbon dioxide growth rate.

b. Programmed Goals

(1) For global baseline monitoring, approximately six stations will be established in very "clean air" without nearby agriculture or pollution sources. Examples are Mauna Loa and Antarctica. Some stations will be operated in collaboration with foreign Governments, for example a New Zealand station. Assurance of long-term participation of each station must be obtained. The program is designed to provide the minimum number of stations that will enable the United States to detect secular changes of global significance even if no other Government undertakes a similar effort.

(2) Primary measurements will initially consist of continuous ground-level measurments of carbon dioxide, the chemistry of precipitation, solar radiation attenuation (including spectral distribution), ground-level dust loadings, and vertical distribution of atmospheric particulates (see following paragraph for lidar program). Later, the additional measurements including the electrical properties of the atmosphere, the freezing and condensation nuclei concentrations, and the composition of particles relevant to climatic change will be undertaken along with measurements of other chemicals and compounds.

(3) The measurement of the vertical distribution of atmospheric particulates at baseline stations will be made by ground-based remote-sensing lidar. Although lidars currently in operation do not have this capability, systems of adequate sensitivity are within the current state of technology. A program of supporting research to refine the technique will be performed and prototype lidar equipment developed, installed, and tested at the first global baseline station.

2. Regional Land Station Monitoring

a. Requirements

(1) In addition to the determination of trace constituents of manmade and natural origin in "clean air", it is necessary to monitor by regions the trends of airborne contaminants in the conterminous United States. Such data will relate the changes in character of population distributions and in technological concentrations to the contaminant levels. They will also assist in establishing regional differences which may exist within the conterminous States.

(2) To determine the cumulative impact of pollutant emissions into the atmosphere, it is important to document the change in air quality with the sweep of the atmosphere, generally from west to east over increasing densities of population and industrialization. Stations are required to collect precipitation for measuring the chemical constituents and to measure the attenuation of the solar beam caused by particulates along the west coast, in the intermountain regions, in the Midwest, and along the eastern seaboard at locations that are not near major urban centers. These regional monitoring stations should have the capability

to provide additional air quality observations to other governmental agencies and to those organizations with a particular interest in geophysics.

b. Programmed Goals

(1) Approximately 10 NOAA stations that are geographically distributed over the conterminous United States will be selected for regional monitoring. (It is likely that global baseline stations will also be located in the States of Hawaii and Alaska and will make the same measurements listed below). These regional stations will be in nonindustrialized settings where nearby significant changes in land usage are unlikely or are likely to occur slowly.

(2) Initially, the measurement program will consist of the observations of atmospheric turbidity and of the constituents of precipitation. Later, the monitoring will increase to include air filtration (dust loadings), with possible chemical and physical analysis of the particles, and collection and measurement of freezing and condensation nuclei. Selected stations also will be equipped with advanced solar radiation measurement systems. (See para. B. 1. below for details on the solar radiation observation network.)

(3) The basic concept is to combine the equipment and laboratory facilities of the Environmental Protection Agency (EPA) with the widespread observational coverage and competence of NOAA. Measurements initially will be confined to turbidity and monthly precipitation collection made by NOAA using photometers, special rain collectors, and analysis of chemical constituents provided by EPA. When the ice nuclei observation program is established, no problem is foreseen in collocating this program at these same NOAA stations.

3. Oceanic Baseline Observations

a. Requirements

Initial measurement and monitoring is necessary for those oceanic constituents, properties, and processes likely to influence climatic change. Initially and, as a practical matter, because of the vastness of the oceans and the complexities of their processes, only baseline sampling of properties directly related to the ocean-atmosphere interface is needed to attain the present objectives. A quantitative assessment needs to be made of the carbon dioxide reservoir of oceans and the continuous exchange with the air. The role of the ocean as a transporter of potential airborne pollutants and its role as a cleaner could be significant in the cycle of contaminants. The existence of widespread oil film and changing thickness could be a factor in evaporation and in surface temperatures as well as significant to the wind-sea surface momentum exchange. The marine environment must

be studied to observe and understand climatic changes resulting from natural phenomena and from man's activities. Consequently, ocean observations are required that will detail the physical and chemical properties of the oceans. These data will serve a dual purpose, in that they will provide input for quantitative studies of oceanic mixing and organic productivity and, at the same time, serve as a baseline for levels of gases and the particulate interchange between the atmosphere and the sea.

b. Programmed Goals

(1) The ocean monitoring program for climatic change will be included as an integral part of the much larger NOAA Plan in preparation for monitoring critical environmental quality factors in the ocean and for developing prediction techniques of these factors needed to conserve the oceans' living resources and to provide effective management of the coastal zone, the offshore waters, and the deep oceans. For climatic change purposes, the ocean monitoring program must adequately measure:

(a) The amount of carbon dioxide exchange between the ocean and atmosphere.

(b) The atmospheric fallout at land and ocean stations in the vicinity of primary and secondary wind systems.

(c) The heat budget of the mixed layer of the oceans.

(d) The changes in areal extent of polar ice, with emphasis on the Arctic Basin.

(2) A preliminary investigative study will be made to determine the extentavailable data must be supplemented as to type and amount by the above large-scale baseline oceanic sampling program to derive secular carbon dioxide content over oceans and secular changes in thermal energy of the mixed layer. This study will develop the most effective future monitoring program to include other ocean properties contributing to climatic change.

4. High Altitude Sampling and Sensing

a. Aircraft Sampling

(1) Requirements

The measurement of the chemical constituents of particles, concentration of gases, and amount of water vapor primarily in the lower stratosphere is the basic requirement. It will be necessary to sample the atmosphere between the altitudes of approximately 50,000 and 65,000 feet along north-south lines extending from Alaska into the Southern

Hemisphere. Presently, only aircraft are available to accomplish this task. The frequency of the flights should be about once every two weeks in the temperate latitudes and once every month to once every three months for the other latitudes. The primary sampling requirement consists of filtration to monitor the quantity and chemical composition of dust and the measurement of water vapor content, both in situ, by means of a frostpoint hygrometer and in the solar beam by sensing the solar radiation.

(2) Programmed Goals

(a) Initially, the goal is to develop an aircraft monitoring system. Significant developments and equipment purchases needed include:

- Development, under contract, of the required pure filters that must be laboratory-controlled during manufacture and handling to permit reliable chemical analysis of low concentration of particles.
- Development of chemical analyses techniques and development of new sampling instruments for high-speed aircraft.
- Procurement of frostpoint and optical hygrometers especially designed and adapted for aircraft use.
- Coordinated development of sampling techniques with aircraft operators and controllers. A few test-sampling flights would be undertaken to check the system before expansion and application.
- Acquisition of the required support aircraft capable of making an adequate flight profile in the lower stratosphere; the RB57F, for example, is a possible aircraft to use.

(b) The development of scientific and technological expertise is essential. This goal demands the careful attention of knowledgeable scientists because contamination and other problems associated with the aircraft platform and the low concentrations can otherwise yield meaningless results. Later as techniques are perfected, sampling techniques will be extended or developed to measure certain gases in the lower stratosphere such as hydrocarbons, sulfur dioxide, nitric oxide, and nitrous oxide and to provide a continuous record of particle concentration.

b. Satellite Sensing

(1) Requirements

(a) Even though the present capability is extremely limited, ultimately, the use of space platforms for global monitoring may permit the utilization of data secured by this means for use in climatological analysis. Such data would not be available from local monitoring stations.

(b) Although the use of high ground-resolution sensors on satellites to monitor local small-scale pollution sources, trajectories, and composition does not appear now to be cost-effective and the measurement of the local concentrations of various gaseous constituents is not considered practicable from satellite platforms, there are other requirements that, given proper sensors, can be met by satellite systems. These include:

- Long-term global monitoring of large-scale distribution patterns of particulate matter and gaseous constituents.
- Evaluation of radiation budgets of the entire earth and its atmosphere. (See para B.1. below for net radiation and heat balance requirements.) (An experimental instrument, the Earth Radiation Budget Radiometer, is being designed and built in the National Environmental Satellite Service, under contract to the National Aeronautical and Space Administration for flight on the Nimbus F experimental satellite late in 1973. The instrument will measure specifically the incoming and reflected short-wave radiation and the upwelling long-wave radiation at the satellite altitude.)
- Long-term monitoring of changes in urban development, land-area patterns, and thermal characteristics of lakes, rivers, and estuaries. The Earth Resources Technology Satellite (ERTS) will be well suited for supplying the basic data for this requirement.

(c) A priority requirement is the long-term measurement of the earth's albedo. Globally integrated measurements from satellites are the most promising means for providing this information.

(2) Programmed Goals

(a) To adapt current capability and to develop future space platforms for a greater role in monitoring parameters pertinent to atmospheric quality, early funding in research and development (R&D) projects will enable urgent work to begin on feasibility studies and on some design and development of prototypes. Priority considerations will be given to applications of the earth radiation budget measurements, characteristics of lasar systems for aerosol measurements, and advanced spectroscopic techniques for gaseous constituent measurements.

(b) To establish the long-term trends of the earth's albedo, reliable measurements will begin as soon as possible. The R&D will be initiated on feasibility studies for exploiting satellite capabilities to obtain more accurate quantitative information on the earth's albedo; for example, onboard calibration of the visible wavelength radiometer will be used to obtain satellite cloud images.

B. Radiation and Contaminant Distribution

1. Heat Balance

a. Requirements

(1) The fundamental parameter in the development of climate is the earth's ability to absorb and re-radiate heat, that is, to maintain its heat or radiation balance. Basic information, therefore, is required on the received, reflected, and net solar radiation and on significant changes in the global albedo, land usage, and thermal emissions. Knowledge of the amount and distribution of solar radiation received at the earth's surface is essential. To obtain such information requires a solar radiation observation network of properly located and equipped stations. Because of the need for global coverage of solar radiation observations, it is necessary that the United States participate and assist those international programs directed toward this coverage.

(2) Long-term measurements of the earth's albedo are required to determine how natural and man-induced changes affect this radiation balance. Clouds are a major factor in the albedo value. Since the year-to-year variability of cloudiness may be expected to be quite high, long-term, globally integrated measurements of albedo are necessary. Man is most active in changing the character of land utilization through the construction of roads, the building of cities, the conversion of forests to agricultural lands, and the introduction of large-scale irrigation. Periodic determination of land usage that results in generally similar albedo characteristics is an important need.

(3) Surveillance of the increasing emissions of sensible heat from man's activities is required because these emissions could change atmospheric conditions on a local or even regional basis. Projections of the increasing requirement for energy and its concentration in large power-production complexes point towards heat emissions, over a small area, which begin to approach a significant fraction of the net solar energy received. Because all production of power, whether by fossil fuels or nuclear energy, emits heat which must eventually be dissipated into the earth, ocean, or atmosphere, quantitative monitoring of these emissions is required as a part of the environmental quality system.

(b) Programmed Goals

(1) To insure that the current solar radiation measurement program operates reliably with standard procedures and compatible observations, a system for quality control will be established to include periodic inspections of National Weather Service (NWS) observation stations and active liaison with the cooperative observing stations. Obsolete and wornout equipment will be replaced. To further international coordination and to assure standardized observations and equipment calibration, the World Meteorological Organization (WMO) Regional Center and the U.S. National Solar Radiation Center will be combined at Washington, D.C.

(2) As set forth in paragraph A. 4.b. (2)(b) above, reliable measurements of long-term trends of the earth's albedo will begin as soon as possible. Satellite instrumentation would be eminently suitable for long-term documentation. While achieving this capability may require 5 to 10 years, the importance of long-term globally integrated measurements of albedo requires immediate application of resources for feasibility studies and for design and development of prototype instruments.

(3) Changes in land usage are being studied by other agencies for various purposes through the use of airborne and satellite sensors. Integration and expansion of these measurements to give global coverage and to distinquish trends in land usage, especially in the percentage of the earth's surface covered by forest, will be undertaken. Such measurements will not be taken continuously, although surveys may be required at 2- to 5-year intervals. The forthcoming ERTS spacecraft should be capable of this task.

2. Contaminant Cycle and Emission Rates

a. Requirements

Contaminants are injected into the atmosphere by natural activities (such as volcanism, ocean spray, and dust storms) or through man's activities (in such areas as power production and transportation. These contaminants are transported by the atmosphere, may change character through photochemical or chemical reactions, and are eventually removed from the atmosphere by dry sedimentation or precipitation scavenging. Once deposited on the earth or in the oceans, the contaminants then may enter into this cycle again. Predictions of environmental quality require:

- Quantitative determination and future estimates of emission rates (from both man and nature).
- Determination of the distribution of transported material in the earth's atmosphere and the changes brought about during this transit.
- Quantitative knowledge of the removal mechanisms which cleanse the atmosphere, yet deposit the contaminants on the surface.

b. Programmed Goal

Comprehensive research and studies will be undertaken to establish sources for emission data, both nationally and globally; to assemble these data in a form usable by the meteorologist in global models; and then to return the results to the general public and the scientific community. Emission data identification, assembly, and restructuring will be necessary to permit the use of data in environmental quality prediction. This identification and assembly of data will be completed before a determination is attempted to identify the precise natural and industrial wastes that are significant in climatic change. Associated with these emission studies will be field experiments and laboratory studies of such features as precipitation removal of particles, gas and photochemical reactions, transport, repositories, and other contaminant cycle factors.

C. Analysis and Prediction

1. Analysis and Interpretation

a. Requirements

Initial research efforts are required to understand the mechanisms causing changes in the concentration of atmospheric constituents which may affect the future state of global and mesoscale weather. The expressed purpose of the global geophysical monitoring network is to monitor the changes in these constituents. Understanding the mechanisms that bring about these changes are most important, particularly the effect of contaminants entering weather processes in two important mechanisms: the radiation budget and the cloud and precipitation processes.

b. Programmed Goals

Concurrent research efforts will be undertaken in the following areas:

- Determination of all relevant and measurable parameters and identification and development of techniques to meet the needs for monitoring additional atmospheric constituents.
- Initiation of studies on the life history and residence time of various gaseous and particulate pollutants.
- Determination of the life history of cloud condensation and freezing nuclei from manmade and natural sources.
- Analysis and interpretation of data from the global and regional monitoring stations, aircraft, and environmental satellites to determine the very small but significant trends.

- Comprehensive investigation of the overall problem of climatic change including predictability, man's influence, and impact of climatic change on man.

2. Geophysical Modeling

a. Requirements

Computer modeling of the atmosphere is well underway, but needs to be intensified to develop the necessary sophistication of models and to react in response to the timeframe required so as to evaluate the existing and short-term changes in air quality. To be able to simulate the consequences of human activity in the past century as well as into the future, critical additional physical interactions must be devised and introduced into current models. These interactions involve the radiative properties of a large class of natural and artificial aerosols, cloud formation, ocean and atmosphere exchange and buffering, and surface hydrology including snow and ice stages. To provide a reliable basis for anticipating long-term consequences, modeling research must be intensified immediately. At the same time as models become suitable for application to specific, inadvertent modification, sufficient resources are necessary to conduct comprehensive experimental series that can be considered definitive. This situation requires additional talented scientific teams to design and conduct the experiments skillfully and to interpret the results. Equally essential is the acquisition in FY 1973 of the most powerful computers to minimize mathematical errors and to permit an adequate number of experiments over sufficiently long simulation periods.

b. Programmed Goals

Current R&D programs for modeling the planetary boundary layer and its responses to new technology will be accelerated with the emphasis on the climatic change problem. Experiments designed to determine the nature and extent of changes in the climate of the world as a result of pollutants will be undertaken. For example, principal efforts will be directed toward determining the long-term effect of a change in the content of carbon dioxide in the global atmosphere-ocean system and the effect of increased water vapor in the stratosphere introduced by jet aircraft. Completion of these goals will assure achievement of the overall objective to predict changes in climate resulting from man's activities.

D. Support Activities

1. Quality Control System

a. Requirements

Determination of trends in environmental quality requires that measurements be made over many years, probably for at least two decades.

To establish these trends on a firm basis, the measurement techniques used must be based on rigid and reproducible standards. Instrumentation must be compared with reference standards and be calibrated at specific intervals to insure against electronic, optical, or other deterioration. Observer quality control methods must be established and statistical techniques to detect deviations be formulated and instituted. Inter-calibration of equipment and procedure is required because much of the program involves collection of samples and later laboratory analyses. It can be expected that new and more sophisticated laboratory techniques will be evolved and that these techniques must be compared with previous systems. Also, intercomparison of results from different laboratories using standard samples is necessary to insure meaningful data. As new instrumentation is developed to measure, for example, trace constituents, simultaneous measurements by both old and new techniques will be required over a sufficient period of time to insure the stability of the new methods in comparison with previous standards. It is exceedingly important to emphasize this aspect of the problem. Recent redetermination of the oxygen content of the atmosphere depended almost entirely on the conclusion drawn from extremely precise and careful work done 60 years ago. Without such quality control, instrument calibration, and reference standards, long-term geophysical monitoring lacks meaning.

b. Programmed Goal

Development and study efforts will be initiated to establish standards for various measurements, criteria for trends, and statistical methods vital for monitoring on a global scale. An in-house competence will be established to evaluate quality control procedures and standards. Standard gases mandatory for comparative analysis will be procured from the National Bureau of Standards. Advanced analytical chemical criteria and standards for atmospheric constituents will be developed.

2. Data Archiving

a. Requirements

The success of any monitoring program requires that data be collected and accumulated over significant periods of time. This requirement is necessary to permit trend analyses and predictions in a wide range of time scales and in correlation with the general state of air and water environments. An adequate program, therefore, must be developed for careful and complete central collection and storage of the data in full detail, in forms suitable for retrieval and use in a variety of time-series analyses, and in correlation with conventional meteorological and oceanographic data. Samples which have not been reduced to digital, computer-readable forms will require reduction to such forms to permit their analytical use.

b. Programmed Goal

The archiving system will be designed for routine, timely summariza-

tion and dissemination of the data for use by other Federal and local agencies concerned with environmental quality control. To safeguard the reliability of the data, adequate measures will be taken for quality control of the data collection, reduction, analysis, and storage process. The data will be indexed and catalogued to facilitate search and retrieval; careful description and qualification of the samples and sampling methods will be made available to permit intelligent use of the data in a variety of analyses.

E. National and International Coordination

1. U.S. Government and Scientific Agencies

a. Requirements

Global baseline and regional monitoring stations, newly established to support this Plan, will initiate a stable long-lived base of observational locations that are available for additional monitoring. The presence of associated meteorological information and a trained observational staff will make these locations of interest to other governmental agencies. It is necessary for NOAA to cooperate with agencies requesting additional monitoring through the establishment of programs sufficient to meet the monitoring needs of these other agencies. Close coordination and planning to reduce the total governmental cost must be an integral part of this program.

b. Programmed Goal

The global baseline and regional monitoring stations will be used collaboratively with other governmental agencies requiring information on the long-term trends in atmospheric properties not related to climatic change. Examples of such potential interest by other agencies might be: radioactivity by the Atomic Energy Commission, pesticides by the EPA or the Department of Agriculture and heavy metals in contaminant particles by the Department of Health, Education, and Welfare or the EPA. Funding for those additional efforts would be supported by the requesting agency. This program will require association and collaboration with governmental and scientific groups that have major efforts, studies, or responsibilities in environmental monitoring. The mechanism for this needed coordination will be through the Office of the Federal Coordinator for Meteorological Services and Supporting Research in accordance with Office of Management and Budget Circular A-62.

2. International Agencies

a. Requirements

It is necessary that this Plan fits within the framework of a broad category of programs of the United Nations(UN) and of non-governmental international organizations. The World Meteorological Organization (WMO), a UN agency, is the focus for the internationally sponsored World Weather Watch, which allows for an extensive, routine

monitoring of the atmosphere on a global basis. The United States is a major participant in the program recently adopted by the WMO for establishing a global network of pollution monitoring stations.

b. Programmed Goal

The planned program for global baseline land stations will be consistent with the WMO background-sensing network; the U.S. network would be part of this larger WMO capability. Data from this entire worldwide system will be available to the United States. To further the program, NOAA will continue close cooperation with the WMO and such non-governmental activities as the Global Atmospheric Research Program. Such participation will be performed through existing international arrangements.

III. PROGRAM COSTS

Attachment A is a summary of the estimated costs of this Plan; the organization of the attachment identifies the costs of achieving the programmed goals in five phases, each corresponding to a fiscal year. The initial implementation costs of phase I and backup details are included in attachment B. With the exception of that portion of the programmed goals listed under Support Activities, the major efforts can be implemented more or less independently. The establishment and operation of the global baseline and the regional land and oceanic baseline monitoring systems have priority.

Some of these cost estimates require adjustment as the results of the initial R&D efforts are applied to the program and the need for new equipment, procedures, and research becomes apparent. Geophysical monitoring for climatic change and the associated prediction role are new global endeavors; allowance must be made for dynamic developments. For these reasons, additional funding increments have not been estimated for any phase beyond the first full year of operation of any R&D project.

Attachment A

Costs of Achieving Programmed Goals

(In thousands of dollars and additive except for FEC)

Programmed Goals	Approp.	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
		Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K
1. Global Baseline Land Stns.											
a. Mauna Loa staff & equip.	S&E	2	50	2	50	0	0	0	0	0	0
b. Mauna Loa lidar prototype	R&D	0	150	0	-150	0	0	0	0	0	0
c. Activation of new stations	FEC	0	640	0	640	0	320	0	0	0	0
d. Baseline station operation	S&E	0	0	6	300	6	300	3	150	0	0
e. Addition of equipment for baseline stations	R&D	0	0	0	200	0	0	0	-100	0	-100
	FEC	0	0	0	0	0	100	0	200	0	200
2. Regional Land Stations											
a. Preparation of 10 existing stations	S&E	0	15	0	-15	0	0	0	0	0	0
b. Addition of equipment	S&E	0	0	5	100	5	100	0	0	0	0
	FEC	0	0	0	100	0	100	0	0	0	0
3. Oceanic Baseline Observations											
a. Development of observation program	R&D	2	50	0	0	-2	-50	0	0	0	0
b. Baseline observations	S&E	(Cost depends upon results of above R&D study)									

Attachment A

Costs of Achieving Programmed Goals - Cont'd

(In thousands of dollars and additive except for FEC)

Programmed Goals	Approp.	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
		Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K
4. Aircraft Sampling											
a. Aircraft techniques & procedures	S&E	2	40	0	0	-1	-20	0	0	0	0
b. Procurement of pure filters	R&D	0	100	0	0	0	0	0	0	0	0
c. Chemical sampling instrument	R&D	0	300	0	-100	0	-100	0	0	0	0
d. Procurement of frostpoint hygrometers	FEC	0	150	0	0	0	0	0	0	0	0
(Note: Cost of RB-57F R&D flights are not included. Estimate is $1500/hr with 1,000 hours per year scheduled by phase 4.)											
5. Satellite Sensing											
a. Atmospheric quality monitoring	R&D	5	300	0	0	0	0	0	0	0	0
b. Albedo measurements	R&D	6	500	0	0	0	0	0	0	0	0
6. Solar Radiation Measurements											
a. Surface observation network	S&E	6	110	0	0	0	0	0	0	0	0
	FEC	0	200	0	50	0	0	0	0	0	0
c. Solar radiation center	S&E	3	90	7	110	0	0	0	100	0	-100
	R&D	0	100	0	200	0	0	0	0	0	0
	FEC	0	100	0	200	0	0	0	0	0	0

Attachment A

Costs of Achieving Programmed Goals

(In thousands of dollars and additive except for FEC)

Programmed Goals	Approp.	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5	
		Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K	Pos.	Costs $K
7. Emission Inventory and Rates											
Data identification and assembly	R&D	4	100	0	0	0	0	0	0	0	0
8. Contaminant Cycles and Removal											
Studies & field experiments	R&D	5	300	0	200	-2	-300	0	0	0	0
9. Analysis & Interpretation											
Data analysis & change process	R&D	8	300	2	175	0	0	-5	-200	0	0
10. Geophysical Modeling											
Models for climatic prediction	R&D	2	100	8	300	0	0	0	0	0	0
11. Quality Control System											
a. Development procedures and standards	S&E	2	50	0	0	0	0	0	0	0	0
b. Procurement of standard gases	R&D	0	50	0	-50	0	-50	0	-50	0	0
c. Development of chemical criteria	R&D	0	100	0	0	0	-50	0	0	0	0

Attachment A

Costs of Achieving Programmed Goals - Cont'd

(In thousands of dollars and additive except for FEC)

Programmed Goals	Approp.	Phase 1 Pos.	Phase 1 Costs $K	Phase 2 Pos.	Phase 2 Costs $K	Phase 3 Pos.	Phase 3 Costs $K	Phase 4 Pos.	Phase 4 Costs $K	Phase 5 Pos.	Phase 5 Costs $K
12. Central Data Archiving											
System for storage and retrieval	S&E	2	100	0	0	0	0	0	0	0	0
TOTALS	S&E	17	455	20	545	10	380	3	150	0	0
(Note: these costs do not include ocean baseline observations and aircraft flying hours.)	R&D	32	2450	10	775	-5	-450	-5	-450	0	-200
	FEC	0	1090	0	990	0	520	0	200	0	200

(General Note: S&E - Science and Engineering; R&D - Research and Development; and FEC - Facilities Equipment, and Construction; and $K - in thousands of dollars.)

Attachment B

Initial Implementation Costs -- Phase I

Line Item	S&E Pos.	S&E Costs $K	R&D Pos.	R&D Costs $K	FEC Pos.	FEC Costs $K
1. Global Baseline Land Stations	2	50	0	150	0	640
2. Regional Land Stations	0	15	0	0	0	0
3. Oceanic Baseline Observations	0	0	2	50	0	0
4. Aircraft Sampling	2	40	0	400	0	150
5. Satellite Sensing	0	0	11	800	0	0
6. Solar Radiation Measurements	9	200	0	100	0	300
7. Emission Inventories and Rates	0	0	4	100	0	0
8. Contaminant Cycles and Removal	0	0	5	300	0	0
9. Analysis and Interpretation	0	0	8	300	0	0
10. Geophysical Modeling	0	0	2	100	0	0
11. Quality Control System	2	50	0	150	0	0
12. Central Data Archiving	2	100	0	0	0	0
Phase I Totals	17	455	32	2,450	0	1,090

Note: S&E - Science and Engineering; R&D - Research and Development; FEC - Facilities, Equipment, and Construction; $K - in thousands of dollars.

1. Global Baseline Land Stations (2 positions, $50,000, S&E); (0 positions, $150,000, R&D); (0 positions, $640,000, FEC)

a. The $50,000 in S&E appropriation will provide for a two-man staff to conduct an expanded mission at Mauna Loa. This expansion includes modernization of equipment necessary for continuous ground-level measurements of carbon dioxide, chemistry of precipitation, attenuation of solar radiation, and determination of vertical particulate distribution.

b. The $150,000 in R&D funds will provide for procurement, installation, and testing of the first particulate profile system at Mauna Loa. It will provide one man-year for the operation and for the development of data-handling techniques. (The funds will buy the early prototype model and begin the field test.)

c. The $640,000 in FEC appropriation will provide for the construction and equipping of two additional global baseline land stations equivalent in capability to Mauna Loa.

2. Regional Land Stations (0 positions, $15,000, S&E)

The $15,000 S&E funding will equip 10 existing first-order NWS stations geographically distributed over the conterminous States with the capability to measure and report atmospheric turbidity and to collect precipitation for an analysis of chemical constituents. This equipping of stations is a joint effort with EPA, which will provide instructions and instruments.

3. Oceanic Baseline Observations (2 positions, $50,000, R&D)

An initial investigative study will determine whether available data are of the type and in sufficient amount to derive the secular carbon dioxide content over the oceans and the secular changes in thermal energy of the mixed layer. The $50,000 in R&D funds will provide for two people who are necessary to do this analysis and to develop an effective future observational program involving other ocean properties that could contribute to climatic change.

4. Aircraft Sampling (2 positions, $40,000, S&E); (0 positions, $400,000, R&D); (0 positions, $150,000, FEC)

a. The $100,000 in R&D appropriation will go to the contract development of the required pure filters that must be laboratory-controlled during manufacture and handling to permit reliable chemical analysis of low concentrations of particles.

b. The $300,000 in R&D funds will provide for laboratory chemical analyses and will begin new sampling development for high-speed aircraft.

c. The $150,000 in FEC appropriation will procure the frostpoint hygrometers especially designed and adapted for aircraft use and the Canadian-designed optical hygrometers, also needed for aircraft.

d. The $40,000 in S&E funding will provide the two personnel who are needed to coordinate and develop sampling techniques with aircraft operators and controllers. The processing of samples will be accomplished. A few sampling runs would be undertaken to complete the system for future expansion and application.

(These funds do not include costs of the required aircraft, the RB57F, for example, that are capable of an adequate flight profile in the lower stratosphere. Aircraft requirements will approximate 1,000 hours per year at $1,500 per hour. The U.S. Air Force has the current capability to provide this support for which the funding has not been discussed. Because of the continued, if not the expanded responsibility of NOAA for global high-altitude sampling, the acquisition of this capability by the Research Flight Facility may be the most economical.)

5. Satellite Sensing (11 positions, $800,000 R&D)

a. $300,000 of R&D funds will provide the five people needed to initiate a major new effort to develop a sensor capability for satellite monitoring of aerosols and gaseous atmospheric constituents related to air pollution. This information will also be used in interpreting outputs from other satellite sensors to improve the accuracy of quantitative data such as atmospheric temperature profiles. Investigations of microwave radiometry and lidar-sensing techniques, beginning in FY 1971, will provide the basis for instrument development.

b. The $500,000 in R&D appropriation will fund the required initial study to develop satellite capability for providing long-term measurement of the earth's albedo. The fundamental parameter in the development of climate is the earth's ability to absorb and re-radiate heat: its radiation balance. Long-term measurements of the earth's albedo are required to determine how natural and man-induced changes affect this balance. Clouds are a major factor in the albedo value. Because the spatial variability of cloudiness may be expected to be quite high, long-term globally integrated measurements from geostationary satellites or from a lunar base would be eminently suitable for long-term documentation. Six positions will be filled.

6. Solar Radiation Measurements (9 positions, $200,000 S&E); (0 positions, $100,000, R&D); (0 positions, $300,000,FEC)

The $110,000 in S&E funding will provide the six people for periodic inspection of all National Weather Service (NWS) solar-observing stations and for liaison with cooperative-observing stations. This funding is necessary to ensure that the solar radiation measurement program is operated in an effective manner and that data from all observing stations are compatible. One position will be based in each of the six NWS Regional Headquarters. The $250,000 in FEC funds will be used to replace obsolete and wornout equipment at 60 NWS observing stations with up-to-date solar radiation measurement systems.

The $90,000 in S&E funding will provide three people to begin staffing the combined WMO Regional and U.S. National Solar Radiation Center. This number must be increased to 10 positions to staff properly the Center with physical scientists and technicians to operate the facility.

Washington, D.C., has been designated by the WMO as a Regional Center for Solar Radiation Measurements. Such a facility will be combined with and serve as a calibration laboratory for observing systems used in the U.S. National Solar Radiation Network. The $100,000 in R&D appropriation will enable support of work already begun by others on the development of an absolute standard instrument for solar radiation measurements. The $50,000 in FEC appropriation will start the funding needed to provide standards, calibration equipment, and facilities for the combined WMO Regional and U.S. National Solar Radiation Center.

7. Emission Inventories and Rates (4 positions, $100,000, R&D)

Much data exist on the natural and manmade releases of pollutants into the atmosphere. The $100,000 in R&D funds would provide four people to establish sources for emission data, both nationally and globally, and to assemble these data in a form useable by the meteorologist in global models. These data identification and assembly are necessary before determination can be made as to the precise industrial wastes that are significant in climatic change.

8. Contaminant Cycles and Removal (5 positions, $300,000, R&D)

Predictions of future atmospheric concentrations of pollutants depend on both their source and life cycle. The $300,000 in R&D funding will enable five persons to start laboratory studies and field experiments of such features as precipitation removal of particles, gas and photochemical reactions, transport, and repositories.

9. Analysis and Interpretation (8 positions, $300,000, R&D)

It is of the utmost importance to distinquish between the human and the natural factors responsible for climatic variation and to anticipate the future course of each.

Eight positions and $300,000 in R&D funds are required to initiate research efforts leading to an understanding of the mechanisms that cause changes in the concentration of atmosphere constituents which may affect the future state of global and mesoscale weather. The expressed purpose of the global geophysical monitoring network is to monitor the changes in these constituents. Understanding the mechanisms that bring about these changes is most important. Pollutants entering the weather processes affect two important mechanisms: the radiation budget and the cloud and precipitation processes. Concurrent research efforts are needed in the following areas:

- Determination of all relevant and measurable parameters and identification and development of techniques to meet the needs for monitoring additional atmospheric constituents.

- Initiation of studies on the life history and residence time of various gaseous and particulate pollutants.

- Determination of the life history of cloud condensation and freezing nuclei from manmade and natural sources.

- Analysis and interpretation of data from the global and regional monitoring stations, aircraft, and environmental satellites to determine the very small but significant trends.

- Comprehensive investigation of the overall problem of climatic change, including predictability, man's influence, and impact of climatic change on man.

10. Geophysical Modeling (2 positions, $100,000, R&D)

Two research meteorologist positions and $100,000 in R&D funds are needed to observe and to model the planetary boundary layer and its response to new technology. Man's energy production capability already equals the radiational energy of the sun over small areas and is increasing rapidly. Large-scale projects for water diversion and massive irrigation will add significant amounts of water vapor to the lower atmosphere, changing the character of the earth's surface and its heat radiative character over large sections. This geophysical model development program will include the assessment of the effects of water diversion and irrigation projects on heat balance and moisture distribution and, through boundary layer models, will provide the necessary link to models of global weather and climate. The results of research will assist in the determination of the most economic means for introducing new technology, while at the same time preserving environmental quality. The program will be closely coupled to studies of other agencies on air pollution, power production, and water resources. This program responds to the President's program for the Protection and Enhancement of Environmental Quality and to the National Environmental Quality Act of 1969.

11. Quality Control System (2 positions, $50,000, S&E); (2 positions, $150,000, R&D)

This funding will establish the standard criteria and statistical methods vital to determing trends on a global scale. Without strict quality control, instrument calibration, and reference standards, long-term geophysical monitoring is without meaning.

a. The $50,000 in S&E funds will provide two people to develop in-house competence to receive, process, and archive data.

b. The $50,000 in R&D funds will procure from the Bureau of Standards standard gases mandatory for comparative analysis.

c. The $100,000 in R&D appropriations will fund for advanced analytical chemical criteria and standards.

12. Central Data Archiving (2 positions, $100,000, S&E)

The $100,000 in S&E funds will activate the system for careful central collection and storage of monitoring data gathered worldwide. The program will develop the processing and storage format for retrieval and will be used in a variety of time-series analyses, including digital computer-readable form. Timely summarization and dissemination of the data for use by Federal and local agencies can then begin. Two positions will be filled.