WORLD WEATHER PROGRAM

PLAN FOR FISCAL YEARS 1980 AND 1981

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PLAN FOR FISCAL YEARS 1980 AND 1981

DEPARTMENT OF COMMERCE
DEPARTMENT OF DEFENSE
DEPARTMENT OF STATE
DEPARTMENT OF TRANSPORTATION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SCIENCE FOUNDATION

To The Congress of the United States:

Our ability to forecast the weather and understand the dynamics of climate are essential national resources if we are to develop and execute effective strategies for dealing with energy use. The unsettling world events over the last year have demonstrated how interwoven are our national goals with those of other countries. This is especially true with respect to international meteorology. The World Weather Program was formulated so that the United States could join with other countries to set joint goals to better understand and forecast the global weather which affects us all. The ready exchange of data and ideas, and the sharing of resources to attain these World Weather Program goals has been done through the successful Global Atmospheric Research Programs sponsored by the World Meteorological Organization and the International Council of Scientific Unions and the operation of the World Weather Watch, a program central to the World Meteorological Organization.

I am pleased to transmit to Congress, in accordance with Senate Concurrent Resolution 67 (1968), this World Weather Program Plan which describes the significant activities and plans of Federal agencies. The plan details the U.S. contribution in FY 1980 and FY 1981 to international meteorology through the World Weather Watch in order to develop improved worldwide weather observations and services and the U.S. effort to conduct a comprehensive program of research supporting the further development of the World Weather Program.

Jimmy Carter
The White House
April 1980

Foreword

Begun as an aid to sailing ship captains, the organized collection and international exchange of meteorological data has continued uninterrupted for over 125 years. During these years, technology has been a spur pushing meteorologists to extend their capabilities both in forecasting and understanding the weather. The telegraph was introduced just prior to the Civil War and allowed the first synoptic, or simultaneous, description of the weather at many locations on the surface. The development in the 1920s of inexpensive radiosondes carried aloft by balloons provided the capability to probe the upper atmosphere on a synoptic basis. Satellites in the early 1960s gave the first comprehensive view of the weather over the entire Earth. Large computers were developed to assimilate the enormous amount of meteorological data being obtained and gave rise to the term "automatic data processing." The next logical step was to apply this technological capability to examine the global weather systematically.

Chapter 1 describes the decade-long effort to plan and execute the Global Weather Experiment. It is not an experiment with the weather. Rather, it is an experiment with techniques of observing and studying the weather. It focused the technology at hand, devised new technology to meet special demands, and for one year the Global Weather Experiment dominated international meteorology. The success of the Operational Year (December 1978-November 1979) has been such that the effort to use the data obtained will dominate international meteorological research for the next decade.

Chapters 2 and 3 contain a summary of Federal Agency plans and programs to meet the challenges of international meteorology for the two-year period, FY 1980-1981. These efforts directly or indirectly contribute to the goals of the World Weather Program.

A fiscal summary of these programs is contained in the concluding section.

All FY 1980-1981 dollar amounts shown in this plan are reflected in the President's budget, and the data shown here should be used for planning purposes only. The scheduling and implementation of the U.S. programs after FY 1981 in support of the World Weather Program are subject to further analysis and judgment.

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1. The Global Weather Experiment

Historical Development

An unprecedented analysis of the atmosphere of planet Earth is underway with the involvement of over 140 countries, the United Nations, and the International Council of Scientific Unions. It is The Global Weather Experiment--the largest international scientific experiment yet attempted. The Global Weather Experiment is not an experiment with the weather. It is an experiment with techniques of observing and studying the weather.

After many years of planning, the Operational Year began in December of 1978. Following the operational phase which ended in November 1979, a multi-year evaluation and research program commenced and will continue until the late 1980s. During this period, scientists and technicians will examine the atmosphere, the sea surface, and the upper layer of the world's oceans in the most intense survey and study ever made.

Unusual International Cooperation

While helped by the increased availability of radar, aerial photography, and increased observational coverage from growing numbers of aircraft and ships after World War II, meteorology in the 1950s was hindered by insufficient observational tools and coverage, inadequate communications networks, and meager computational capacity.

The theoretical base in thermodynamics was strong. There was a good, very general map of the largest, apparently continuing atmospheric features--prevailing winds, storm regions, temperature belts, and the like. The shape of storms was becoming known. Countries accelerated their exchange of weather data. Still, the picture of atmospheric circulation was rough at best. A larger more cohesive international view was needed.

* Major portions extracted from: (1) "The Global Weather Experiment - An Informal History," by Gerald S. Schatz, National Academy of Sciences; (2) "The Global Weather Experiment - 1. The Observational Phase Through the Second Special Observing Period," by R. J. Fleming, T. M. Kaneshige, and W. E. McGovern, National Oceanic and Atmospheric Administration.

Through the International Council of Scientific Unions, academies and their special committees from more than 60 countries organized and coordinated participation, with support from their governments, in the 1957-1958 International Geophysical Year (IGY). The IGY led the way not only to international cooperation in the Antarctic but also to cooperation elsewhere including the establishment of a set of world data centers for the exchange and archiving of the growing volume of data.

On September 25, 1961, addressing the United Nations General Assembly, President Kennedy put forth a series of arms-control proposals and called for a program of peaceful uses of outer space. In that connection he announced, "We shall propose further cooperative efforts between all nations in weather prediction and eventually in weather control." With the International Geophysical Year clearly a happy and recent memory and with national meteorological agencies anxious to move, initial consensus on definitions and direction came swiftly. UN General Assembly Resolution 1721 (XVI), on international cooperation in peaceful uses of outer space, was enacted on December 20, 1961.

The Mandate Emerges

What would become the Global Atmospheric Research Program and the World Weather Watch had begun to take shape. The encouragement to cooperate in operational weather services was clear, and the research program's two-part mandate--to advance weather forecasting and to improve the understanding of the physical basis of climate--had been written.

In April 1963, the World Meteorological Organization (WMO) issued its <u>First Report on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space</u>. This was the detailed response to U.N. General Assembly Resolution 1721 (XVI). On December 13, 1963, the General Assembly enacted its Resolution 1963 (XVIII) formally endorsing efforts to establish a World Weather Watch (WWW) and reiterating endorsement of international cooperation in meteorological training and meteorological research.

By 1966, the International Council of Scientific Unions had established a Committee on Atmospheric Sciences, and the World Meteorological Organization had established its own Advisory Committee. These committees met jointly in 1966 and agreed to joint sponsorship of a Global Atmospheric Research Program. The World Meteorological Organization is an intergovernmental, specialized agency of the United Nations and coordinates the World Weather Watch. The International Council of Scientific Unions, for which the National Academy of Sciences is the U.S.

adhering body, is nongovernmental.

In 1967, the World Meteorological Organization adopted an implementation plan for the five elements that would make up the World Weather Watch (a global observing system, a global data processing system, a global telecommunications system, a research program, and an education and training program). In 1967, the World Meteorological Organization and International Council of Scientific Unions signed the papers jointly, formally launching the Global Atmospheric Research Program to be administered by a Joint Organizing Committee. Participation in the Global Atmospheric Research Program would be the principal research activity of the World Weather Watch.

The Concept

The global experiment is simple in broad concept. For brief periods, the routine weather observations of the World Weather Watch were to be augmented greatly. Much of the data would be processed immediately at several centers, and, perhaps as a result, the routine forecasting services might improve slightly. Those data would also be made available to archives and research units, which would not attempt to produce quick forecasts but would attempt to produce more accurate analyses and longer range forecasts for study purposes.

By late October 1978, plans for the observing system included: World Weather Watch surface and upper-air stations; polar-orbiting satellites from the United States and the Soviet Union; geosynchronous satellites from the United States, Japan, and the European Space Agency; other research satellites; instrumented commercial aircraft and merchant ships; 300 Southern Hemisphere drifting buoys; and special aircraft, balloons, dropsondes, tropical wind observing ships, and oceanographic ships.

Highlights of the Operational Year of the Global Weather Experiment

The design of the observational program required more than a decade of planning. The primary motivation for the experiment is to explore the possibilities for greatly extended prediction of the atmosphere's behavior through the use of advanced observing techniques, computer capabilities, and numerical models. The indispensable foundation for the development of such a capability is an adequate body of global data for research which is sufficiently accurate, detailed, and complete to permit scientists to distinguish between prediction errors due to failures in observation and those errors due to failures in understanding. The task of the experiment's planners was to design an observing system that could both acquire these global data and actually be implemented.

Virtually all of the 147 countries of the WMO participated in the Global Weather Experiment through the existing World Weather Watch observing system. Some 67 countries and seven international institutions provided special contributions of additional observing systems and data-management elements for the Global Weather Experiment and the associated regional experiments (POLEX, MONEX, and WAMEX). As designed, the composite global observational system included the elements in Table 1.1. Figure 1.1 shows the time schedule for activities of the Global Weather Experiment.

Elements of the Composite Observing System

WWW GLOBAL OBSERVING SYSTEM SURFACE-BASED SYSTEM

Since the initial planning of the Global Weather Experiment, it has been obvious that the required observations could be met only through a composite observational system. At the heart of this system is the WWW Global Observing System (GOS) Surface-Based Subsystem, which includes land upper-air and surface stations as well as commercial aircraft and voluntary observing ships. Implemented in 1967, the WWW consists primarily of the surface and upper-air stations of the member countries of the WMO, the mobile ship stations, commercial aircraft, and various meteorological satellites. Observations are currently exchanged in real-time via the Global Telecommunication System (GTS).

The growth of the WWW has been slow but steady. For the Global Weather Experiment, many countries improved their upper-air observations and provided complete reports in a delayed mode. Table 1.2 is a summary of the amount of WWW upper-air data received at NOAA's National Meteorological Center (NMC) at various times prior to and during the experiment.

Because of the importance of measuring the wind field in the tropics, the United States temporarily implemented four upper-air stations in the equatorial Pacific for the Special Observing Periods (SOPs). These stations were located at Eniwetok (11.4°N, 162.4°W), Woleai (7.4°N, 143.9°E), Kapingamarangi (1°N, 154.8°E), and Canton (2.8°S, 171.7°W). In addition, the station at Fanning (3.9°N, 159.4°W), which had been temporarily implemented for the North Pacific Experiment (NORPAX) on a six per week observational schedule, was augmented to a two per day schedule throughout the SOP.

Table 1.1

Observational System*	Coverage
The WWW surface and upper-air stations	Global
Four polar-orbiting meteorological satellites	Global
Four geostationary meteorological satellites	Global
Research satellites	Global
Special aircraft releasing windfinding dropsondes during a 30-day period within each of two special observing periods over the Atlantic, Pacific, and Indian Oceans	Tropics (10° N-10° S)
Approximately 50 ships releasing windfinding sondes during the special observing periods	Tropics† (10° N-10° S)
Over 300 drifting buoys	Southern Hemisphere
150 balloons released during each special observing period to float near 140 mbar	Tropics
Commercial aircraft and merchant ships equipped with meteorological instruments	Global

* Additional observing systems associated with the regional experiments are not listed.

† More than 50 ships participated, but not all were operational at the same time.

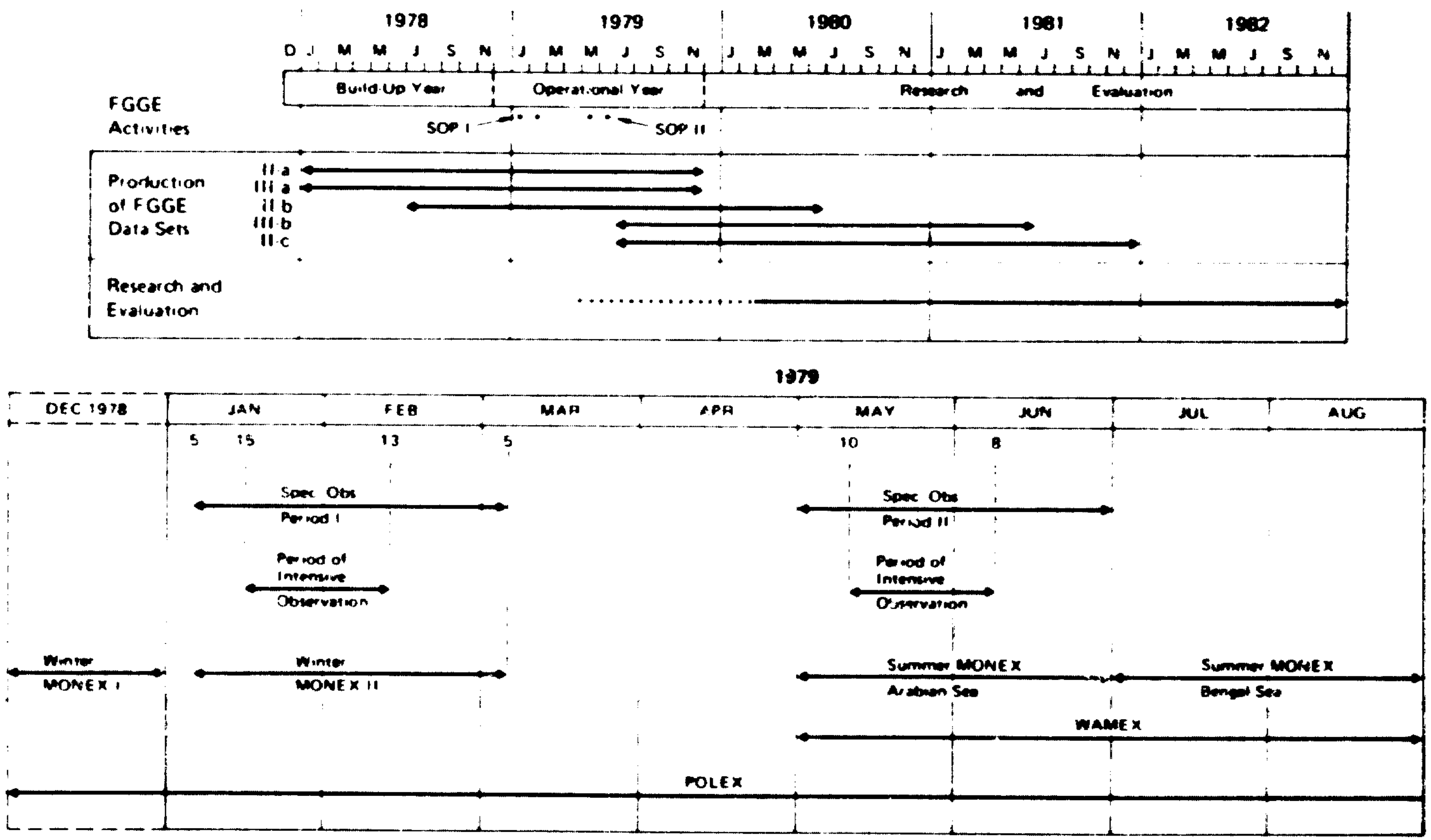

Figure 1.1 The time schedule for activities of the Global Weather Experiment.

Table 1.2 - Average Daily Number of Upper-Air Observations Collected by the WMC Washington During the Global Weather Experiment

	Land and Ocean Stations
Early buildup year (estimated)	2,200
Early operational year (Dec. 1-Jan. 4)	2,704
SOP-1	2,748
SOP-1 Intensive	2,776
SOP-2	2,818
SOP-2 Intensive	2,846

Seven other U.S. stations, located within the $10^{o}N-10^{o}S$ zone and part of the World Weather Watch basic observing network, were also augmented from one to two observations per day during the SOP (Ascension, Diego Garcia, Truk, Ponape, Majuro, Koror, Yap).

Several other countries added new or temporary upper-air stations for the Global Weather Experiment and/or the associated regional experiments. Some of these were in developing countries with resources provided by developed countries through the WMO's Voluntary Co-operation Program.

SPECIAL SURFACE-BASED OBSERVING SYSTEMS

Automated Aircraft Reports

Manually determined and communicated weather information is currently available from most commercial aircraft. However, the Global Weather Experiment benefited from a special effort by The Netherlands in processing automated data from several countries' commercial aircraft which provided very accurate wind and temperature information. About 80 aircraft (subsets of the DC-10, B-747, and Concorde fleets) equipped with Aircraft Integrated Data Systems (AIDS) recorded meteorological and engineering data on cassette recorders for delayed processing.

AIDS aircraft provided over 600,000 wind and temperature reports during the Experiment. Countries (airlines) participating included Austria (QANTAS), Denmark/Sweden/Norway (SAS), Netherlands (KLM), Philippines (PAL), Switzerland (Swiss Air), Thailand (Thai International), United Kingdom (British Airways), United States (TWA), and Venezuela (VIASA).

A real-time system of obtaining accurate wind and temperature information from wide-bodied jets equipped with inertial navigation systems was also developed for the Experiment. This system is called Aircraft to Satellite Data Relay (ASDAR). Seventeen aircraft of eight International airlines were equipped to send data in real-time (eight data points sent once an hour) via the data collection system on board the geostationary satellites. This system developed by NASA and NOAA, was tested in a quasi-operational mode during the Global Experiment and is expected to become a part of the future WWW. Over 250,000 wind and temperature reports were provided by the ASDAR aircraft.

Aircraft Dropwindsonde Program

The Aircraft Dropwindsonde Program provided a significant portion of the direct observations of vertical wind profiles required in the equatorial tropics. During the Intensive Period, the United States aircraft flew on six long-range missions making dropwindsonde observations (sondes descending by parachute from the aircraft) along the tracks at 350-km intervals and included vertical profiles of wind, temperature, and humidity.

Daily flights were flown in the latitude belt 10^{o}N-10^{o}S as follows: three sorties in the Pacific Ocean (round-robin tracks west from Hawaii and south from Acapulco, Mexico, and a shuttle between Honolulu and Acapulco); two sorties in the Indian Ocean (round-robin tracks east and west from the island of Diego Garcia); and a single sortie in the Atlantic Ocean (round-robin from Ascension Island). All sorties in the Pacific and Atlantic were flown by U.S. Air Force C-141 aircraft. The Indian Ocean sorties were flown by two P-3s and a C-130 operated by the Research Facilities Center of NOAA. Over 4,000 successful soundings of the important tropical wind were obtained by this United States system.

Tropical Wind Observing Ships (TWOS)

Strategic ocean gaps in the tropics not covered by the aircraft tracks, WWW land stations, or island stations were filled by some 40 oceanographic research vessels classified as Tropical Wind Observing Ships (TWOS). These ships provided twice daily vertical profiles of wind, temperature, and humidity. Some of these ships were dedicated to the Experiment as TWOS, while others provided the atmospheric data as a secondary mission to their primary oceanographic activities.

Countries that provided ships included Australia, Brazil (2), Peoples Republic of China (2), France (3), FRG (2), GDR, Hong Kong, India (4), Japan (2), Mexico (2), Peru, Philippines, Senegal, Spain, USSR (13), and USA (6). Most ships had a new low-maintenance windfinding system provided through WMO. This WMO system was funded by contributions from Saudi Arabia, the United States, the United Nations Development Program, and the United Nations Environmental Program. Finland agreed to provide the delayed processing of the data for the Experiment.

Tropical Constant Level Balloons (TCLB)

Above the ships and aircraft, at approximately 14,300 meters, constant density balloons provided measurements of wind and temperature during the SOPs. Approximately 160 balloons were launched each period by scientists from the National Center for Atmospheric Research (NCAR). Balloons were launched from Ascension Island, Couton Island, and Guam (SOP-2 only) and were located by the French-built ARGOS data collection system onboard the United States TIROS-N satellite system. Processing of the location data provides at least two winds per day from each platform, and these data will supplement the wind field information obtained from the other tropical wind-measuring systems.

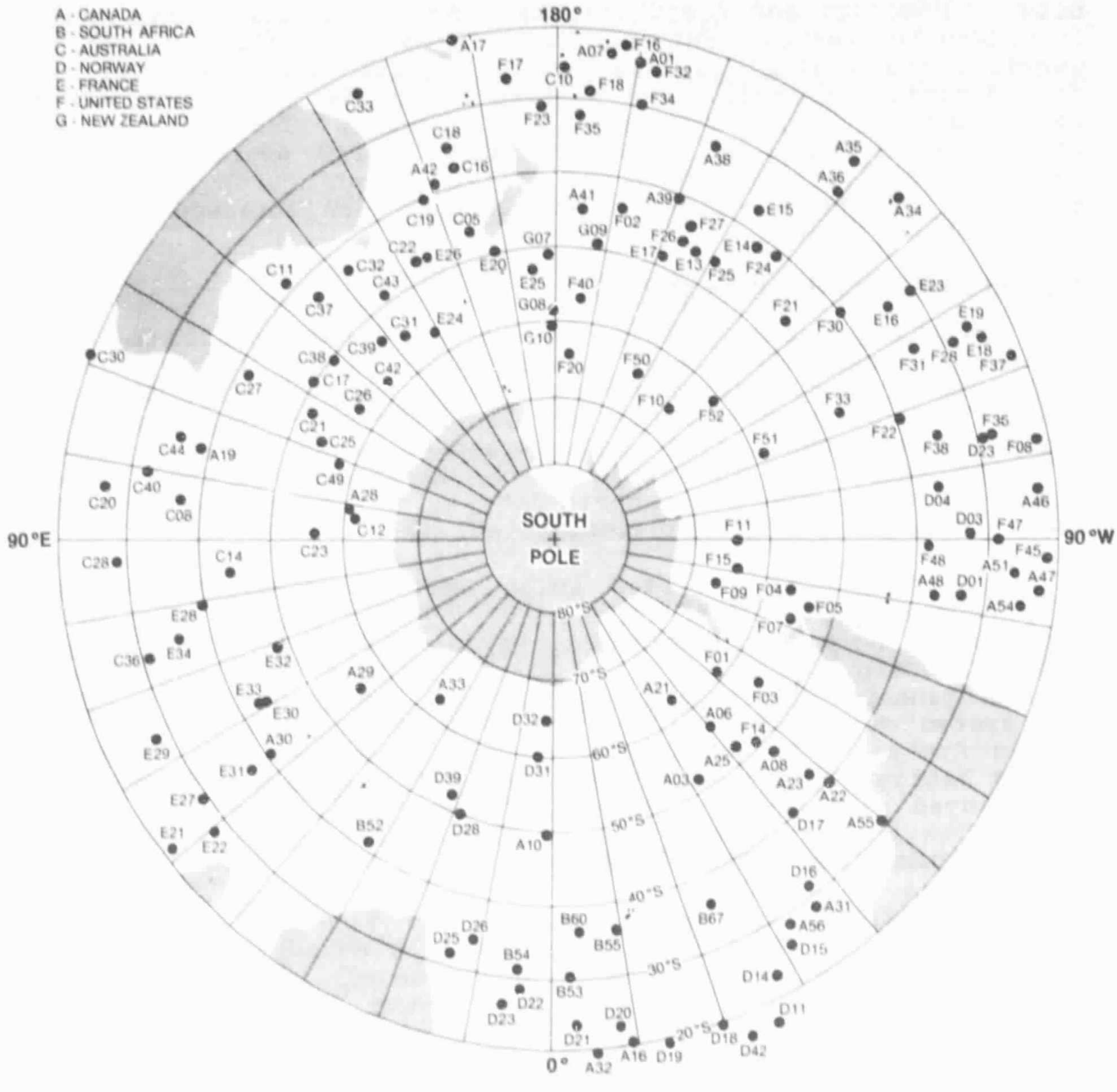

Figure 1.2 Location of operational drifting buoys in the southern hemisphere on February 15, 1979.

Southern Hemisphere Drifting Buoys

The large ocean areas and the low ship traffic in the southern hemisphere result in comparatively few surface observations from this region. However, "reference level" measurements, in particular surface barometric pressure measurements, are essential for maximum utilization of information from the satellite observations. To meet this need, eight countries (Australia, Canada, France, New Zealand, Norway, South Africa, United Kingdom, and United States) contributed over 300 drifting buoys to the Experiment. Equally important, 14 countries (Argentina, Australia, Brazil, Canada, Chile, Federal Republic of Germany, France, Japan, New Zealand, Norway, South Africa, United Kingdom, United States, and USSR) agreed to deploy the buoys over the southern hemisphere oceans. These buoys are designed to drift with the currents and to monitor surface atmospheric pressure and sea-surface water temperature to within ± 1 mb and $\pm 1^{\circ}$C, respectively.

By January 15, 1979, 147 buoys had been launched and 126 were operational. By February 12, 193 had been launched and 165 were operational. Figure 1.2 provides a snapshot view of the buoy positions as of February 15, 1979. The drifting buoy data are received via the ARGOS collection and location system aboard the TIROS-N satellite and are relayed to France through United States ground stations for processing and insertion onto the GTS.

WWW GLOBAL OBSERVING SYSTEM

Geostationary Satellites

A system of five geostationary satellites has been strategically placed around the equator and serve as a vital part of the composite observing system for the Global Weather Experiment. The location of these satellites is indicated in Figure 1.3. Three of these (provided by Japan (GMS), the European Space Agency (METEOSAT), and the United States (GOES-Indian Ocean)) were positioned primarily to support the Experiment. In addition to the many scales of motion discernible from the sequences of images obtained from these satellites, one can also obtain cloud-motion vectors from successive visible and IR images. These cloud-motion vectors provide an indication of the wind field in an area of approximately 50° from the satellite subpoint. Winds are deduced for two or three levels. These cloud-motion vectors are especially valuable near the equator where there are relatively few land stations and where knowledge of the wind field is so essential. During the experiment, NESS produced 40,000 wind vectors monthly.

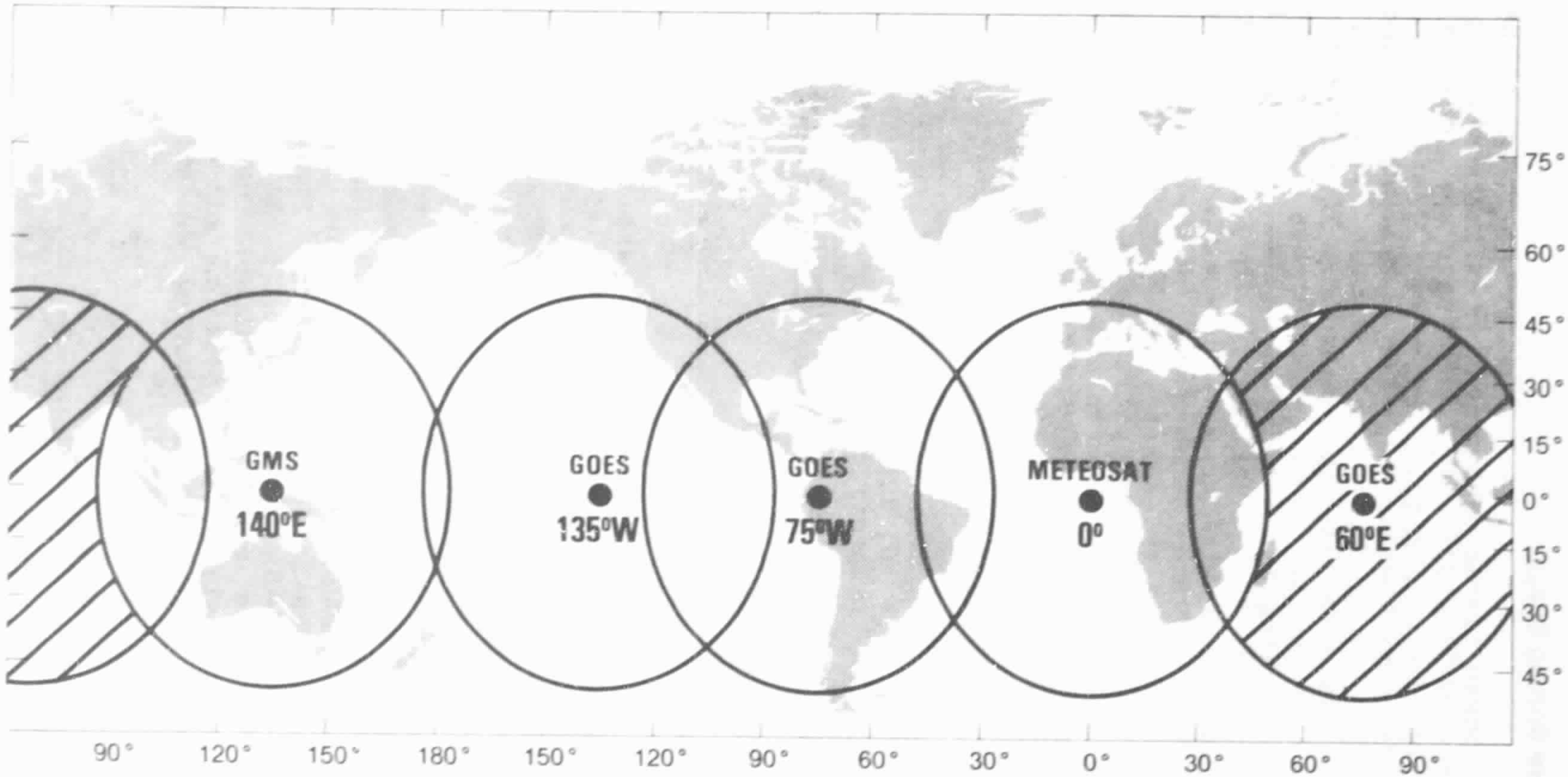

Figure 1.3 Geostationary satellite coverage during the Global Weather Experiment.

The United States has maintained two geostationary satellites under simultaneous operation for several years. These have been systems from the Synchronous Meteorological Satellite (SMS) and Geostationary Operational Environmental Satellite (GOES) series. During the Operational Year GOES-3 or GOES-West (at 135°W) operated flawlessly. However, GOES-2 (also called GOES-East at 75°W) experienced early problems with the precision latitude stepping mechanism of the Visible and Infrared Spin Scan Radiometer (VISSR). SMS-1, an older backup satellite already in orbit, was moved slowly eastward by NOAA's National Environmental Satellite Service (NESS) from its standby position (92°W on January 9) to 75°W on January 26. On that date GOES-2 imaging operations were terminated and SMS-1 became known as GOES-East.

Japan launched its first geostationary satellite in the summer of 1977. Located at 70°E, the satellite provides a unique view of atmospheric events in that part of the globe including the winter monsoon. Sea-surface temperatures (SST) are derived from this satellite, and during the first three months of the Experiment over 41,000, 10-day mean SSTs were obtained. Also during this time period, upwards of 500 wind vectors per day were obtained.

The European Space Agency (ESA) launched its first geostationary satellite in the fall of 1977 and positioned it at 0° longitude. During January and February 1979, 24,727 and 25,997 wind vectors were obtained, respectively. In addition to the visible and IR channels common to all the geostationary satellites, ESA's Meteosat has water vapor images from the 5.7-7.1 micrometer channel data. These unique images promise to offer new insights into various atmospheric processes.

The fifth geostationary satellite was to come from the USSR. But when it was announced that this satellite would be late, an alternate backup plan was immediately implemented with funds provided by NASA, NOAA, and NSF. GOES-1 (a satellite already in orbit with certain systems inoperative) was moved to 58°E to obtain images over the Indian Ocean area--to benefit both the Global Weather Experiment and the Summer Monsoon Experiment. The United States could only operate two geostationary satellites simultaneously. Implementation of the third satellite over the Indian Ocean area became a cooperative effort between ESA and the United States The data were obtained by an ESA receiving station at Villafranca, Spain (Fig. 1.4). The antenna, certain ground equipment, and personnel needed for system installation and integration were provided by the United States. ESA provided ground equipment, personnel, and other support to operate the system 24 hours a day.

Operational Polar Orbiting Satellites

TIROS-N, the first of the third - generation weather satellites, was launched on October 13, 1978. The satellite was placed into a near-polar, sun-synchronous orbit at an average altitude of 854 km. The second satellite in this series, NOAA-A, was launched in late June 1979 into a slightly lower orbit (833 km).

Instruments on TIROS-N include the Advanced Very High Resolution Radiometer (AVHRR) and the TIROS Operational Vertical Sounder (TOVS), which in turn includes the High Resolution Infrared Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). These sounders obtain profiles of temperature and water vapor throughout the atmosphere. Also aboard the satellite is the Data Collection and Platform Location System (the French-built Argos system), a random access system capable of platform location as well as data collection from both moveable and fixed platforms, such as buoys and balloons.

Research Satellites

Two research satellite systems were planned by NASA that were not funded directly as FGGE systems, but for which provisions were made to obtain a portion of the data for the Global Weather Experiment. The first of these satellite systems was SEASAT-A.

The primary aim of the SEASAT program is to evaluate the effectiveness of remotely sensed oceanographic and related meteorological phenomena from a satellite-borne platform in space. SEASAT-A was the first of a series of satellites of this program. However, it ceased functioning on October 10, 1978, after 99 days of operation.

The second satellite system called Nimbus-7 (referred to as Nimbus-G prior to launch) was successfully launched on October 24, 1978, into a sun-synchronous, near-polar orbit. The Scanning Multi-Channel Microwave Radiometer (SMMR), which will provide measurements of sea-surface temperature, ocean-surface wind speed, and atmospheric water vapor over oceans, operated normally. The Limb Infrared Monitor of the Stratosphere (LIMS), which will provide stratospheric temperature profiles, was turned off in June 1979 after seven months of successful operations, because of its limited supply of cryogen cooler.

RELATED OCEANOGRAPHIC EXPERIMENTS

A coordinated ocean program associated with the Global Weather Experiment provides an unprecedented opportunity for

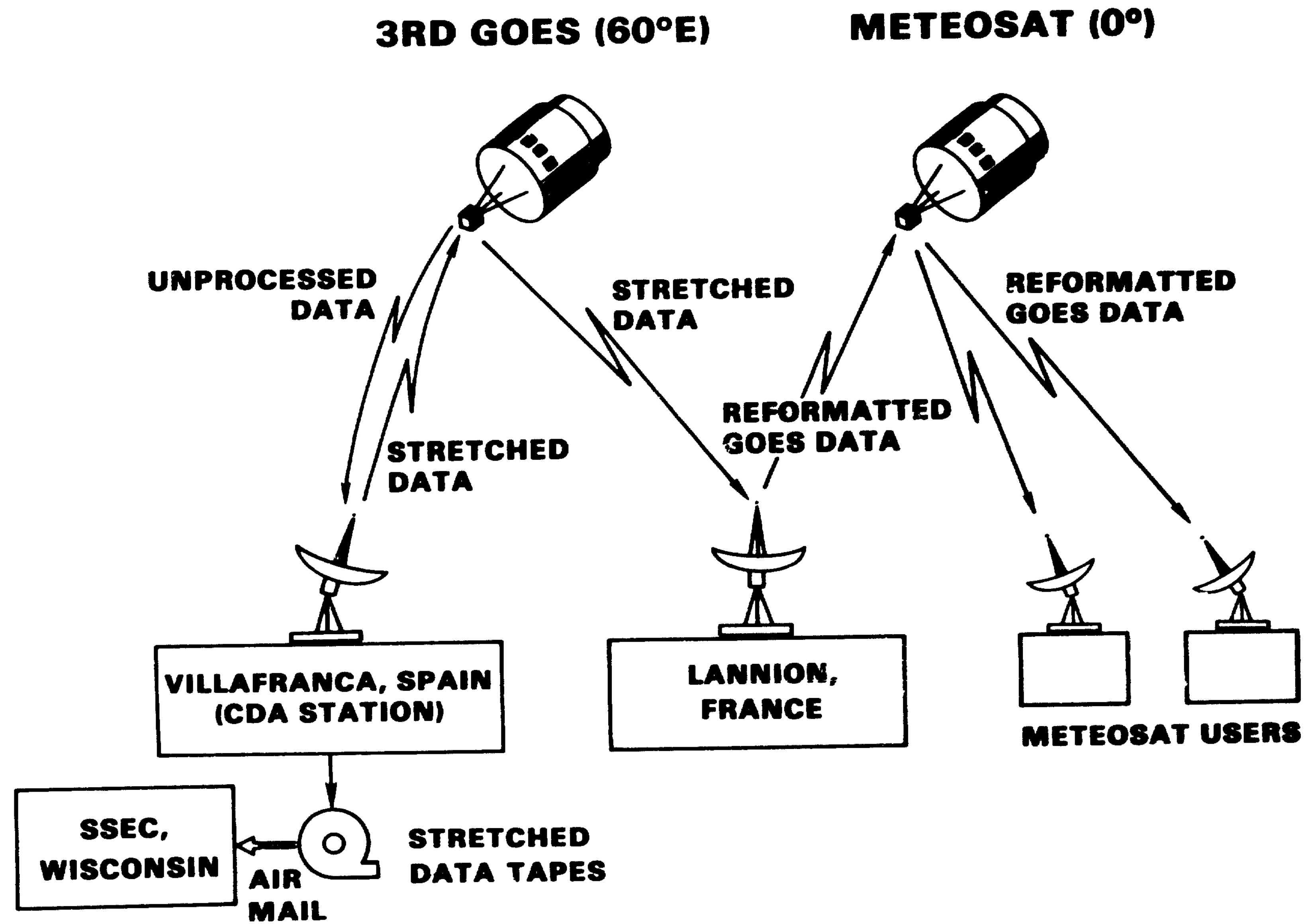

Figure 1.4 Operational data flow for GOES—Indian Ocean.

large-scale monitoring and research aimed at improving our understanding of coupled atmosphere-ocean interactions. To that end, SCOR (ICSU/Scientific Committee on Ocean Research) Working Group 47 has taken the responsibility of coordinating oceanographic activities in the Atlantic, Pacific, and Indian Oceans.

The field phase of various programs began primarily in the three tropical oceans and included ship-based measurements, bottom-mounted sensors, drifting and drogued buoys, and descending probes launched from moving ships. The field phase has been completed, and data reduction has been started.

REGIONAL EXPERIMENTS

Several specialized experiments having to do with significant regional phenomena (Asian monsoons, West African monsoons, and the polar regions) are important elements of the Global Weather Experiment. The principal regional experiments have their own scientific aims. They have provided detailed data for the Global Weather Experiment and will benefit, in turn, from the improved global data set provided by the Global Weather Experiment. Many countries are involved in these regional experiments. The United States provided observing systems in the West Arabian Sea, the Bay of Bengal, the South China Sea, and the polar regions. Reports of these regional experiments will be forthcoming from those principal investigators involved in the Winter Monsoon Experiment (MONEX), Summer MONEX, West African Monsoon Experiment (WAMEX), and the Polar Experiment (POLEX).

The central effort has been on MONEX. U.S. researchers, coordinated by the National Science Foundation, joined with scientists and technicians from 22 other nations (most from the Asian area) to study regional and seasonal fluctuations of the summer and winter monsoons. The experiment took part in two phases. Before the first SOP researchers directed from Kuala Lumpur, Malaysia, concentrated on the South China Sea to study the winter monsoon. During and after the second special observing period, they investigated the summer monsoon, operating from New Delhi to focus on the Bay of Bengal and the Arabian Sea. The aim is to learn more about the physical processes in the "onset" of the monsoon rainy season, develop a detailed description of the monsoon circulation and its interaction with the global circulation, and examine the sensitivity of monsoon circulation to various heat sources. A better understanding of the physical processes that bring both life-giving rains and devastating droughts to the areas is needed to improve extended forecasting. Such improvement could be vital to tens of millions of Asian farmers for whom the monsoons are of critical importance.

The Western African Monsoon Experiment, called WAMEX, was planned to help clarify the three-dimensional structure of the African monsoon and gain a better knowledge of how it is generated and sustained. Researchers in coming years will be studying the interaction of this phenomenon with nearby ocean areas, the subtropical Sahara desert, and the southeast Asian monsoon. They also will look at the monsoons' relationship with ultralong planetary waves, and the desert to the north. For the African nations, the results of such an experiment are important since they have recently experienced the worst drought in their recorded meteorological history.

The United States contribution to POLEX included the air deployment of 20 ice buoys in the Arctic Ocean. These buoys transmitted pressure information to TIROS-N and were located by the ARGOS system on this polar-orbiting satellite. In addition to the valuable pressure information obtained, the buoys provided ice drift information needed for future ice forecasts model improvements for applications in transportation, resource management in polar regions, and understanding climate variations.

Continuing Research Programs of the Global Weather Experiment

OBJECTIVES

The specific research objectives of the Global Weather Experiment can be summarized as follows.

1. To obtain a better diagnostic understanding of the large-scale dynamics of the atmosphere and of critical physical processes;

2. To provide initial and verifying conditions for modeling experiments designed to extend the range of operational weather prediction toward its ultimate limits;

3. To guide the design of an optimum meteorological observing and prediction system for operational weather prediction, which will employ on a continuing basis the technical and scientific knowledge in the Global Weather Experiment; and

4. To investigate, within the limitation of a one-year period of observation, the physical mechanisms underlying fluctuations in climate.

DATA MANAGEMENT

Organizing a research program with such comprehensive objectives is a massive job. The first task has been to organize the data into cohesive sets. The flood of information gathered during the Global Weather Experiment by various weather observing systems is too great to be handled by a single data center. Thus, the initial information processing has been subdivided among 22 data centers throughout the world. Despite numerous delays in the preparation of the research data set, approximately three months of data for the Operational Year have been prepared and data for the remaining nine months are expected to be available by August 1980.

Refined data will be transmitted to World Data Centers in the United States and USSR, and also forwarded to two major meteorological research laboratories for final assimilation and analysis--the European Center for Medium Range Weather Forecasting in Shinfield Park, United Kingdom, and the U.S. Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, N.J. There, scientists utilizing some of the world's largest computers will seek to answer the key questions posed by the Global Weather Experiment.

SEARCHING FOR ANSWERS

How will the scientists answer the central questions of the Experiment? First, it will be necessary to "optimize" the immense amount of information, making it internally consistent. The data for each day of the one-year experiment must be checked for accuracy. All inconsistencies have to be resolved. Making certain that all of the data are realistic and internally consistent will occupy the powerful GFDL computer for the better part of a year. But once the task is completed, the researchers will have the most accurate, comprehensive record of the world's weather ever assembled--more than 14 billion "bits" of information.

These data, the history of the Earth's weather for 365 days, will be the yardstick against which the results of the computer experiments will be measured. Meteorologists will be able to take the data for each day, run their forecasting models, and compare the results with the actual record. They can push their forecasts further and further out in time--until the predictions become of little value.

They can, for example, inject new data every three or six hours and compare the results with models receiving new information every 12 hours. They can cut out certain kinds of data--satellite soundings from the northern hemisphere, high altitude tropical wind data, and so on--and see in each case what happens to their forecast. In this way, it will be possible to evaluate each of the Experiment's observing systems, determining what elements of each may or may not be necessary to produce an accurate, extended forecast. Ideally, the scientists will be able to quantify tradeoffs and come up with recommendations on a weather observing system which will obtain the data needed for an extended forecast of acceptable accuracy--at a price the nations of the world are willing and able to pay.

2. World Weather Program Plan

International cooperation in meteorology have a tradition of over a century, first through the International Meteorological Organization, then under its successor, the World Meteorological Organization (WMO), one of the specialized agencies of the United Nations. This tradition originated with the international exchange of weather data to encourage trade by sea and to enable individual nations to make weather forecasts for their own territories. The United States obtains global weather data through the action of WMO, which arranges and coordinates the international exchange of data.

From its inception in 1968, the World Weather Program has been the mechanism by which the United States integrates world activities directed toward improved weather and hydrologic services and environmental quality. The World Weather Program focuses on: (1) operating and improving the observing, telecommunication, and forecasting systems, (2) extending the range and scope of weather forecasts, (3) understanding the basis of climate and climatic changes, and (4) assessing the consequences of human activities on the global atmosphere. The elements of the World Weather Program are the World Weather Watch (WWW), the Global Atmospheric Research Program (GARP), and the System Design and Technological Development program, which supports both WWW and GARP. This section describes the major elements of the World Weather Program.

World Weather Watch

The United Nations created the World Meteorological Organization as a specialized agency that has grown to 1[illegible]7 members. The WMO functions of coordinating and facilitating the establishment of networks of stations, telecommunication systems, and forecasting centers have been incorporated into the World Weather Watch. Each fourth year the WMO Congress updates the WWW Plan and Implementation Program for the next four-year period. The WMO Congress updated the plan in 1979 for the period 1980-1983. The World Weather Watch is designed as an integrated global system consisting of observation, telecommunication, and data processing functions called, respectively, the Global Observing System (GOS), Global Telecommunication System (GTS), and the Global Data Processing System (GDPS).

In adopting the WWW Plan for 1980-1983, the WMO Eighth Congress agreed that the WWW Programme was the basic program of the Organization in that it provided support for all the other activities in the field of applications and research. The WMO Congress decided to expand the program to include support to agrometeorological activities, the establishment of observing and data-processing facilities necessary for the World Climate Program, and short-term training seminars.

GLOBAL OBSERVING SYSTEM

The Global Observing System consists of two subsystems, which provide meteorological and related environmental observations needed for WWW and GARP: a space-based satellite subsystem using geostationary and polar-orbiting satellites and a surface-based subsystem of surface and upper-air networks for synoptic observations, other stations on land and sea, and aircraft.

Satellite Observations

Growth of the meteorological satellite program has been one of the most productive aspects of the World Weather Watch in the past two decades. The United States has been joined by the European Space Agency (ESA), Japan, and the USSR in operating meteorological satellite systems. Space systems operated by the United States include the polar-orbiting satellites of the NOAA and Improved TIROS Operational Satellite (ITOS) series, and the Geosynchronous Meteorological Satellites (GMS) of the Geostationary Operational Environmental Satellite (GOES) and Synchronous Meteorological Satellite (SMS) series. The ground support systems include facilities to control the satellites and to receive and process the information.

The United States initiated the first stage of an operational GMS system when NASA launched the Synchronous Meteorological Satellite, SMS-1 in May 1974. SMS-2 was launched in 1975. Both are under NOAA operational control. The first Geostationary Operational Environmental Satellite GOES-1 was launched October 16, 1975, GOES-2 June 2, 1977, and GOES 3 June 16, 1978. GOES-2 at 75°W and GOES-3 at 135°W constitute the U.S. operational GMS system. U.S. satellites SMS-1, SMS-2, and GOES-1 remain in orbit, all with partial systems failures, but are usable as backup satellites for special programs. The European Space Agency (ESA) operates a GMS at 0° longitude (launched November 1977) and Japan at 140°E (launched July 1977). This completes the WWW GMS system.

The satellite observation system has grown as the data are proving more useful for meteorological predictions and warnings, oceanographic and hydrologic services, and space environment warning and prediction. New and evolving requirements are leading to more sophisticated satellite systems. The latest is the TIROS-N series of polar-orbiting satellites.

The first of the TIROS-N satellites was launched October 1978; a second to complete the initial TIROS-N System was launched in June 1979. TIROS-N was developed by NASA, and NASA funded the first launch. NOAA is responsible for operating the system, including ground facilities, and for funding subsequent launches.

The four primary spacecraft-instrument systems on TIROS-N are the Advanced Very High Resolution Radiometer (AVHRR), the TIROS Operational Vertical Sounder (TOVS), the Data Collection System (DCS), and the Space Environment Monitor (SEM).

The Advanced Very High Resolution Radiometer provides image data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users, and for storage on the spacecraft tape recorders for later playback. Thus, it continues, as well as improves upon, the present NOAA-5 services related to stored and direct readout of radiometric data for day and night cloud mapping, sea-surface temperature mapping, and other oceanographic and hydrologic applications.

The TIROS Operational Vertical Sounder (TOVS) system combines data from several complementary sounding instruments aboard the spacecraft: The High Resolution Infrared Radiation Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU).

The Data Collection System on TIROS-N, provided by the Centre National de'Etudes Spatiales (CNES) of France, is known as the Argos Data Collection and Platform Location System. It provides two new services not currently in NOAA's GOES data collection system: determining the location of free-floating buoy and balloon platforms by using an inverse Doppler technique; and acquiring platform data from any place in the world, but most advantageously in the polar regions beyond radio reception range of the geostationary satellites.

Surface-Based Observations

The surface-based observing network is comprised principally of the Regional Basic Synoptic Networks (RBSN). Requirements for the RBSNs are determined by Regional Associations. Approximately 735 upper-air sounding stations, 100 optical windfinding sites, 3,800 surface synoptic stations, more than 500 weather radar sites, and 43 moored buoys are part of the surface-based network of the World Weather Watch. The crews of commercial aircraft making international flights provide weather reports at regular intervals. Some 7,300 ships participate in the WMO voluntary observing ship programs, providing most of the surface observations over the oceans. Seven Ocean Station Vessels also obtain upper-air and surface observations at preassigned points in the major oceans.

Buoys

Fourteen of the planned U.S. network of 28 fixed buoys have been moored off the coasts of the United States. Observations reported each three hours include air temperature, water temperature, wind speed and direction, salinity, and subsurface data. Other nations that operate fixed buoys are Australia, Canada, France, Italy, Japan, Norway, Portugal, and the United Kingdom. A half dozen other countries deploy drifting buoys.

Aircraft

Commercial aircraft weather reports are an important source of weather information, especially from aircraft flying over such data-sparse areas as remote oceans and the polar regions. These data are needed to supplement conventional surface and satellite data, and can act as ground truth for deriving temperature profiles and wind estimates from satellite data, and for use in real-time for aircraft route planning.

To improve the quality and spatial distribution of aircraft reports, NOAA and NASA have undertaken two programs to automate aircraft reporting procedures: Aircraft to Satellite Data Relay (ASDAR) and Aircraft Integrated Data Systems (AIDS). In flight, ASDAR data are relayed to ground facilities by way of geostationary meteorological satellites. Four satellites, two operated by the U.S., and one each by Europe and Japan, provide a global data collection capability, with the exception of polar regions above 80° latitude. AIDS data are stored in-flight on a cassette tape for retrieval after one or more flights. The AIDS equipment, while quite cost-effective for collection of research data, is not seen as suitable for development into a real-time operational data collection system.

A third program is under evaluation in which data are sent automatically from aircraft directly to ground receiving stations through the ARINC-Communication, Addressing and Reporting System (ACARS). Six of 11 American Airlines B-747s are already equipped for ACARS in-flight reports. This test program will provide upper-air data over the continental U.S. and adjacent Caribbean through 1980.

Automatic Weather Stations

Automatic weather stations continue to provide needed information for hydrologic, marine, aviation, and agricultural forecast programs and for monitoring climate and pollution.

Increasingly, these stations are transmitting observations via satellite. Canada has applied to transmit from five automated stations through the GOES-1 satellite. Some 30 other Canadian stations are likely candidates. Automated stations in Argentina, Bolivia, and Chile report through GOES-1 on an experimental basis.

Significant progress has also been made in adapting solar power to large automated weather stations. Smaller stations, reporting one to four parameters, have used solar power for several years. NASA has recently demonstrated that the Remote Automated Meteorological Observing Station (RAMOS) can be operated on solar power for about one-tenth the cost of a thermoelectric generator over a 10-year period. Most automatic stations support national programs; however, there is increased emphasis to include them in Regional Basic Synoptic Networks and to exchange the data over the Global Telecommunication System.

Global Baseline and Regional Monitoring

An objective of the World Weather Program is to extend and improve measurements of atmospheric constituents and to assess global effects of manmade and natural constituents on climate. The global monitoring effort includes baseline and regional stations.

Baseline Monitoring. Baseline stations are located in remote areas where air trajectories move great distances over uniform surfaces that are relatively free of manmade and natural pollutants. The U.S. baseline program, which is part of the WMO network, is conducted at four observatories: Mauna Loa, American Samoa, Barrow (Alaska), and the U.S. South Pole Station.

The Mauna Loa observatory has the greatest length of record and variety of measurement programs. It is at an elevation of 3,400 meters (11,150 feet) and samples air trajectories over the Pacific. The measurements are made of carbon dioxide, ozone (surface and column) solar radiation in bands including ultraviolet, aerosols in sites, and vertical profile by lidar and precipitation chemistry.

The American Samoa observatory was completed in 1975. The full-scale measurement program began in early 1976. The University of Rhode Island conducts a cooperative program at the observatory.

The Barrow, Alaska, observatory is located a few kilometers from the Arctic Ocean. The University of Rhode Island and the University of California, Berkeley, operate aerosol programs.

The U.S. South Pole Station observatory used temporary under-snow facilities until early 1977, at which time it was relocated in a new building constructed by the National Science Foundation during the austral summer of 1976-1977. It has a full-scale measurement program.

Regional Monitoring. U.S. regional monitoring stations measure concentrations of manmade atmospheric constituents, particularly those that originate within the contiguous States and cross U.S. national boundaries. All stations measure atmospheric turbidity and collect precipitation for chemical analysis. These measurements make it possible to determine potential increases in aerosols over the United States and the acidity of rainfall, which is high over the eastern United States. Other U.S. stations measure the total ozone in the atmosphere above the station as part of a program to determine long-term ozone trends over the United States. These stations are part of the WMO global ozone network.

GLOBAL DATA PROCESSING SYSTEM

The Global Data Processing System (GDPS) is organized as a three-level system of World Meteorological Centers (WMCs) and Regional Meteorological Centers (RMCs) and National Meterological Centers (NMCs). The World Weather Watch Plan for 1980-1983 includes three WMCs and 25 RMCs. The real-time functions of the system include preprocessing of data, analysis, and forecasting. Nonreal-time functions include collection, quality control, storage, and retrieval as well as cataloging of data for use in research and special application. The 1980-1983 WWW Plan takes full advantage of present-day computer technology, which provides more efficient and sophisticated processing techniques; introduction of new analysis techniques to assimilate satellite and other types of asynoptic data; and introduction of finer mesh models to improve forecast products and services and extend the limits of their usefulness.

World Meteorological Centers

The three WMCs are located in Melbourne, Moscow, and Washington. These centers provide global or hemispheric products which can be used for general short-, medium- and long-range forecasting of planetary or large-scale meteorclogical systems.

The U.S. WMC has three components: the National Meteorological Center at Camp Springs, Md., the National Climatic Center at Asheville, N.C., and part of the National Environmental Satellite Service at Suitland, Md. Historically, numerical models were run using only data collected at specific (synoptic) times. Substantial changes in the global observing sytem, including satellite-derived vertical sounding data and winds, have introduced meteorological data on a nearly continuous basis. New analysis techniques to assimilate these data and improved forecast models have provided the opportunity to prepare guidance on Northern Hemisphere Circulation Patterns for six to ten days in advance.

Regional Meteorological Centers

The 25 RMCs provide regional products (e.g., more detailed or specialized analysis and forecast products) which can be used for short- and medium-range forecasting of small-, meso- and large-scale meteorological systems by NMCs.

The U.S. operates one RMC at Miami, which provides analysis and forecast material (including hurricane and tropical storm information) for the Caribbean, Central America, Northern South America, and adjacent tropical ocean areas. The center has developed a series of statistical models for hurricane prediction. In support of the RMC, the National Meteorological Center has developed a dynamic hurricane prediction model which is run routinely when hurricanes threaten land areas. These models have improved the capability to predict hurricane tracks and landfall. Additionally, the RMC Miami provides, on request, marine and aviation services to foreign countries in its area of responsibility.

National Meteorological Centers

The NMCs satisfy data processing requirements at the national level, relying on products from both WMCs and RMCs, as well as generating other products that are required to execute their responsibilities. NMCs have both real-time and nonreal-time functions as do the global and regional centers and in many instances provide products directly to users of meteorological information.

In addition to its global and hemispheric models, the U.S. NMC utilizes a fine mesh model over the North American and adjacent oceanic regions in support of national requirements. This model runs earlier than global or hemispheric models and is capable of predicting meteorological systems in greater detail. It has also resulted in improvements in forecasts of cloud amount and height, visibility, precipitation, and temperature.

GLOBAL TELECOMMUNICATION SYSTEM

The Global Telecommunication System (GTS) consists of the Main Trunk Circuit and its branches, regional circuits, and national circuits which supplement the global and regional circuits. GTS links together the three World Meteorological Centers, 23 Regional Meteorological Centers that have Regional

Telecommunication Hubs (RTHs), four RMCs that do not have RTHs, and 149 National Meteorological Centers.

GTS transmits about 15,000 bulletins (4,500,000 characters) each day, made up of observational data and processed information in digital form, an additional 2,000 output products of World and Regional Centers, 100 bulletins involving oceanographic data, and other climatic, agrometeorological, and hydrological data.

Main Trunk Circuit and Its Branches

The Main Trunk Circuit (MTC) and its branches consist of 15 segments. It connects the three WMCs and 11 of the Regional Telecommunication Hubs. Six of the RTHs are not automated. Five plan to automate in the near future. Of the 15 operational segments, the Peking-Tokyo segment was the last to become operational. The Moscow-Prague and Moscow-New Delhi segments operate at 1,200 bits-per-second. Other portions, the Prague-Offenbach and Bracknell-Washington-Toyko segments, operate at 2,400 bits-per-second. The Offenbach-Paris segment was upgraded to 4,800 bits-per-second in 1979. Two segments, Cairo-Moscow and Cairo-New Delhi, are planned to be upgraded to 1,200 bits-per-second in the near future.

GTS was able to accommodate the additional traffic generated by FGGE - Global Weather Experiment, and must be engineered to handle increasing volumes of such as that needed by EARTHWATCH, the Integrated Global Ocean Station System (IGOSS), and the World Climate Program. Higher signaling rates will be needed to handle the large amount of satellite data expected, demands of other UN programs, and the stringent time limits set for the transmission of data on the Main Trunk Circuit. A signaling rate of 4,800 bits-per-second is proposed. This task is scheduled for 1980-1983.

Regional Telecommunication Networks

Regional telecommunication networks provide for the rapid collection of observational data at the Regional Telecommunication Hubs (RTHs), particularly those that connect regional circuits with the Main Trunk Circuit. The regional telecommunication networks also provide for the distribution of observations and processed information to NMCs and thus ensure that all Members of WMO receive the data they require.

A network of 247 regional and interregional circuits is recommended. Of these, 196 circuits have been established. They are available for transmission of meteorological data in alphanumeric form.

The United States operates a number of regional circuits in cooperation with other countries in its region. Examples are the high-speed circuit between Washington and Toronto, and the low-speed circuits between Washington and Mexico City and Washington and Nassau. Low-speed circuits also connect Washington with the capitals of the Central American republics and with many of the islands in the Antilles.

VOLUNTARY CO-OPERATION PROGRAM

From the beginning of WWW, it was clear that all countries needed better weather observations and improved communication systems. This was particularly true of some 100 developing countries included in the membership of WMO. Many weather services lacked adequate facilities and trained personnel. Improvement of economic conditions in these countries depended in part on improving their weather services. To help remedy deficiencies and fully implement WWW, WMO established a Voluntary Assistance Program (VAP) in 1967. The name of the program was changed to Voluntary Co-operation Program (VCP) by the WMO Congress (Cg VIII) in 1979.

The WMO-VCP Program helps developing countries implement the WWW Plan by providing equipment, services, and long- and short-term study fellowships. Since the inception of the VCP, this program has provided short-term fellowships in electronics, communications, operation and maintenance of weather data collection systems, electrolytic hydrogen generators, tropical meteorology, and river flood forecasting to students from forty-one countries. Long-term fellowships through which the students received B.S. and Masters Degrees have been completed by candidates from thirty-eight countries from all parts of the globe. Highest priorities are given to facilities needed to support global aspects of WWW. The goal is to eliminate deficiencies in global observations and communications and to establish ground readout stations within range of APT stations so that countries can benefit more fully from satellite weather data.

The United States has contributed $1,500,000 each year to VCP from 1969 through 1976, and $2,000,000 anually from 1977 to 1979. VCP operates on a calendar year basis. Contributions are in three categories: equipment and services (most of the funding), unrestricted cash contributions (about 10 percent), and education and training (10 percent). Total contributions from all WMO members for 1968-1978 were $45,300,000, of which the United States provided $16,000,000 (Fig. 2.1). Since the beginning of VCP, 985 projects have been approved for circulation to members for support. Assistance has been pledged for 634 projects.

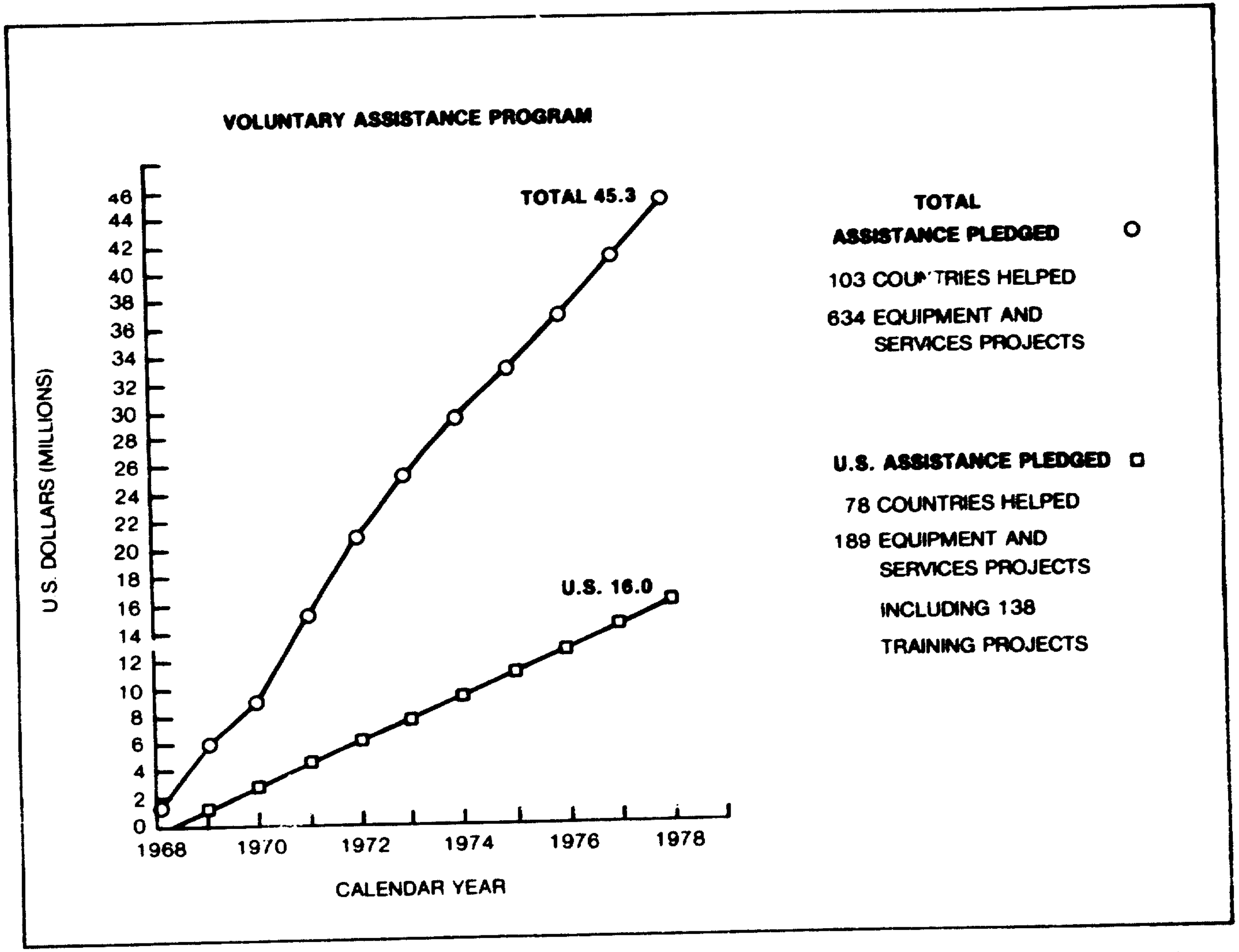

Figure 2.1 Cumulative contributions to the WMO Voluntary Assistance Program by the United States and other nations through 1978.

In preparation for the Global Weather Experiment conducted from December 19, 1978, through November 19, 1979, the United States, under the Voluntary Co-operation Program, offered assistance to some of the developing countries of Africa, Asia, Southwest Pacific, and Central and South America. This offer of support included 15 windfinding radars for obtaining observations of upper-level winds, and 24 Automatic Picture Transmission (APT) Systems that permit direct use of satellite weather data for operational forecasting and severe weather warnings.

The task of managing, coordinating, procuring, shipping, and installing equipment; training foreign personnel; and providing logistical support for all these projects was accomplished by the National Weather Service. The first installation of a windfinding radar system was completed in a remote area of the Amazon Basin at Boa Vista, Brazil, in November 1976, and the last station on the Island of Male in the Maldives, Asia, was completed in February 1979. The 24 APT installations were completed at stations around the world during the same period.

To further assist developing nations improve the quality and reliability of their weather observing and communications programs, the United States, through WMO-VCP, provides technicians to nations in Central and South America to assist in installation and maintenance of observing and telecommunications equipment. VCP also provides short-term training programs for foreign nationals at the National Weather Service's training facility in Kansas City, and long-term fellowships for more advanced training in meteorology leading to the Bachelor of Science degree at U.S. universities.

Through WMO-VCP, three B-747 aircraft of Singapore International Airlines were instrumented with ASDAR. Two technicians were trained in the United States to install and maintain the equipment. The three ASDAR-equipped aircraft began operation in mid-1979.

Global Atmospheric Research Program

The Global Atmospheric Research Program (GARP) is jointly sponsored by WMO, as the research part of the World Weather Program, and by the International Council of Scientific Unions (ICSU). GARP includes theoretical, numerical, and observational experiments designed to improve our understanding of the global atmosphere and to develop and test physical-mathematical models. GARP has two major objectives that may be summarized briefly as: (1) extending the range, scope, and accuracy of weather forecasts; (2) understanding the physical basis of climate and climate fluctuations.

FIELD EXPERIMENTS

Both GARP objectives require the careful investigation of complex physical processes and the mounting of special observational experiments required to formulate and test theories and models. Some processes can be studied through regional experiments. Regional experiments include: the Air Mass Transformation Experiment (AMTEX), which concentrates on the processes of intensive transformations of air moving from cold land over strongly contrasting warmer water; the GARP Atlantic Tropical Experiment (GATE) which was designed to improve our understanding of atmospheric and oceanic processes in the Tropics; the Monsoon Experiment (MONEX), which studies the mechanics of the monsoon circulation; and the Polar Experiment (POLEX), which examines the role of polar regions in global energetics.

The largest experiment of its kind is the Global Weather Experiment which has just entered the research phase. Chapter 1 is a composite summary of the Global Weather Experiment.

WORLD CLIMATE PROGRAM

Climate can foster human activities or hinder them. The variability of climate can be beneficial or it can be violent and disastrous. The Sahelian drought triggered disasters in parts of Africa, and floods along the Ganges have inflicted untold loss and suffering on the peoples of India and Bangladesh. In two successive years, unusually severe winter conditions led parts of North America to experience considerable economic disruption. Locusts, which are highly sensitive to climate, are on the move again in many parts of the semi-arid regions of Africa.

These events have produced a striking and rapidly growing realization by socio-economic planners, as well as by the general public, of the dependence of national economies and welfare on climatic fluctuations. Furthermore, the recognition of the important role to be played by the application of climatic knowledge in planning national socio-economic development has created the need for more effective international action in this field.

The need for the World Climate Program (WCP) is highlighted by:

- A growing world population and rising standards of living make increasing demands upon the finite resources of the environment. The role of climate as a natural resource and the effects of climate variations are magnified as the expectations of these people rise.
- Human activities themselves may alter climate. It is necessary to learn how to avoid undesirable effects or

to plan to live with them if they prove to be unavoidable.

- Studies of past climates have shown that climate changes and variations occur on all time and space scales. Therefore, it is reasonable that significant natural variations can occur within the time frame of human planning.
- New tools have been acquired for advancing our knowledge of climate and its relationships with human society. Among these are new techniques permitting global observation of the atmosphere, land and oceans, as well as new technology for collecting, transmitting, storing, processing, and interpreting such data. These technological advances have been accompanied by equally impressive advances in theoretical understanding and ability to develop models of the climate system that simulate its behavior.

In February 1979 the World Meteorological Organization convened a World Climate Conference - A Conference of Experts on Climate and Mankind - in which more than 350 experts from many nations and international organizations participated. This conference helped to prepare the foundation for the WCP which was adopted by the WMO Eighth Congress in June 1979. This major new WMO program was constituted with four components:

- Climate Data Program (CDP)
- Climate Applications Program (CAP)
- Climate Impact Study Program (CIP)
- Climate Change and Variability Research Program (CRP)

The planning and implementation of such a vast program will require the participation by all nations, many of the United Nations specialized agencies such as FAO, UNEP, and WHO, as well as intergovernmental and nongovernmental bodies such as ICSU.

Earlier, the U.S. Congress had passed Public Law 95-367 (September 17, 1978) directing the President to establish the National Climate Program. The Program elements include (but are limited to):

(1) assessments of the effect of climate on the natural environment, agricultural production, energy supply and demand, land and water resources, transportation, human health, and national security;

(2) basic and applied research to improve the understanding of climate processes, natural and human-induced, and the social, economic, and political implications of climate change;

(3) methods for improving climate forecasts on a monthly, seasonal, yearly, and longer basis;

(4) global data collection, and monitoring and analysis activities to provide reliable, useful, and readily available information on a continuing basis;

(5) systems for the management and active dissemination of climatological data, information, and assessments, including mechanisms for consultation with current and potential users;

(6) measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination; and

(7) mechanisms for intergovernmental climate-related studies and services including participation by universities, the private sector, and others concerned with applied research and advisory services.

An annual report on the National Climate Program will be submitted to the U.S. Congress. In Chapter 3, the World Weather Program Plan touches only on those parts of the National Climate Program which directly involve international activities.

3. United States Program for Fiscal Years 1980 and 1981

Funds for U.S. activities in support of the World Weather Program's three areas of activity--World Weather Watch, Global Atmospheric Research Program, and Systems Design and Technological Development--are identified as:

--direct support, without parentheses, for projects that specifically support the World Weather Program, and

--indirect support, in parentheses, for programs that meet immediate mission needs of the Federal agency, but fulfill a requirement of the World Weather Program (these programs would have been budgeted regardless of U.S. participation in the World Weather Program).

The dollar figures in Chapter 3 are all for FY 1981 and are reflected in the President's budget. Summaries for FY 1980 (allocations) and FY 1981 (budget) are shown in Chapter 4 for each participating agency.

World Weather Watch Implementation

During FY 1980 and 1981 the U.S. program in support of WWW will: (1) maintain a continuous operational geostationary satellite system, (2) maintain the TIROS-N polar-orbiting satellite system, and (3) support the operation of portions of WWW surface-based system. The United States will continue to assist developing nations participate more fully in the World Weather Program through the Voluntary Co-operation Program. A start will be made to make improvements in the World Weather Watch to support the World Climate Program.

SATELLITE OBSERVING

- DOC ($85,935,000); NASA ($36,200,000)

Public Law 87-332, September 30, 1961, provided the first appropriation for a National Operational Meteorological Satellite System. This basic meteorological observing program consists of polar-orbiting and geostationary satellites. The U.S. Department of Commerce (DOC) is the agency responsible for a national operational environmental satellite system. DOC is charged with operating and improving the system to meet the common requirements of all Federal agencies. The objectives of the operational system are:

o Provide global imagery of the Earth and its environment on a regular basis, day and night, including direct readout to local ground stations within radio range of the satellite.

- Obtain quantitative environmental data on a global basis, such as temperature, moisture, winds, radiation flux, and solar energetic particle flux, for use in numerical analysis and prediction programs.

- Obtain near-continuous observations of the Earth and its environment, collect data from remote observing platforms (including automatic weather stations, balloons, aircraft, ships, buoys, and river and tidal stations), and broadcast weather data to remote locations.

- Improve monitoring and prediction of the atmospheric, oceanic, and space environments by developing applications of satellite information.

The DOC program includes procuring and launching the operational environmental spacecraft and sensors of the polar-orbiting system. The TIROS-N series satellites, carrying advanced sensors with improved resolution and accuracy, are needed to provide suitable data input to the more sophisticated numerical models for use in the Basic Environmental Services programs. This third-generation polar-orbiting system was inaugurated with the launch of TIROS-N, the NASA-funded prototype, on October 13, 1978. NOAA-6, NOAA's first operational satellite of this series, was launched June 27, 1979. On July 16, 1979, NOAA-6 became operational, thus fully implementing the third-generation, two polar-orbiting satellite system. The work to be accomplished on the NOAA A-G spacecraft in FY 1981 includes the continuation of fabrication, integration, and testing of NOAA D, E, F, and G; and the environmental testing and launch of NOAA-C. The proposed launch schedule for both polar-orbiting and geosynchronous spacecraft is shown in Table 3.1.

Near-continuous day and night observations from satellites were achieved over the United States and adjacent oceans following the launch of NASA's Synchronous Meteorological Satellites SMS-1 and SMS-2, in 1974 and 1975, respectively. These were the NASA-funded prototypes of GOES 1, GOES 2, and GOES 3, the operational geostationary satellites funded by NOAA which were launched October 16, 1975, June 16, 1977, and June 16, 1978, respectively. One geostationary satellite serves as the eastern operational satellite, located over the equator at 75° West longitude, and another geostationary satellite serves as the western operational satellite, positioned at 135° West longitude. The remainder of the geostationary satellites are providing only limited operational support. The collecting of environmental data from remote observing platforms began in August 1975, when the GOES Data Collection System (DCS) ground station became operational. Broadcast of data to remote locations began during October 1976; space environmental data have been available since shortly after the launch of SMS-1 in

Table 3.1 - Projected launch schedule
Polar-orbiting system

Satellite designator	Planned* launch date	Instruments TIROS N Series
		AVHRR - Advanced Very High Resolution Radiometer
NOAA B	FY 1980	
NOAA C	FY 1981	TOVS - TIROS Operational Vertical Sounder
NOAA D	FY 1982	
NOAA E	FY 1983	SEM - Space Environmental Monitor
NOAA F	FY 1984	
NOAA G	FY 1985	DCPLS - Data Collection and Platform Location System (Argos)
NOAA H	FY 1986	
NOAA I	FY 1987	
		HIRS/2 - Modified High Resolution Infrared Sounder

Geostationary System

Satellite designator	Planned* launch date	Instruments
GOES D	FY 1980	SEM - Space Environment Monitor
GOES E	FY 1981	DCS - Data Collection System
GOES F	FY 1983	VAS - VISSR Atmospheric Sounder (GOES D and Subsequent spacecraft)
GOES G	FY 1985	
GOES H	FY 1986	
		VISSR - Visible and Infrared Spin Scan Radiometer

*Launch Date depends on performance of prior spacecraft.

June 1974. The DOC program in FY 1981 will maintain and improve the two-spacecraft Geostationary Operational Environmental Satellite (GOES) system by continuing procurement of spacecraft and sensors, launch vehicles and services, and ground equipment needed to provide an uninterrupted operational two spacecraft system; and evaluate the potential of the NASA-developed Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS) for operational use.

NASA launched Nimbus 7 in October 1978. All of its sensors have operated successfully. Data from the Earth Radiation Budget (ERB), Total Ozone Mapping Spectrometer (TOMS), the Scanning Multichannel Microwave Radiometer (SMMR), and the Limb Infrared Monitoring of the Stratosphere (LIMS) are being processed as special observations for the Global Weather Experiment data set.

SEASAT, which was launched in June 1978, suffered a massive power failure after 99 days in orbit. However, its sensors did provide a unique data set of observations of the sea surface including wind, sea state, etc., which are being evaluated at present. These data have demonstrated the feasibility of such measurements and have provided the basis for a new initiative by NASA, NOAA, and DOD for FY 1981 in the National Oceanic Satellite System (NOSS).

TIROS N, launched in October 1978, provided the major source of satellite sounding data for the Global Weather Experiment. NOAA was launched in June 1979 to supplement this coverage. The quality and quantity of temperature soundings from these satellites are clearly superior to any previously available.

The Earth Radiation Budget Satellite System (ERBSS), which will serve as a part of a comprehensive climate research program has been approved and is expected to be ready for launch in the CY 1983-1984 time frame.

The Halogen Occultation Experiment (HALOE) is under development for a shuttle launch in 1982 and as a second sensor on the AEM satellite which will carry the Earth Radiation Budget Instrument in 1983 or 1984. HALOE is designed to observe the concentrations of chlorine compounds which have a major role in the chemistry of ozone in the stratosphere.

NASA in FY 1980 and FY 1981 will continue payload definition studies for future global satellite monitoring of the composition of the atmosphere. Sensors to detect both gaseous and particulate pollutants and minor constituents have been successfully flown on the Nimbus 7. These results have demonstrated the utility of such measurements in mapping and predicting the distributions of these constituents possible on a global basis.

FOREIGN ASSISTANCE

- DOS $2,000,000

The implementation of the World Weather Watch Plan is carried out by individual members of WMO, through bilateral arrangements and the Voluntary Co-operation Program (VCP). United States support of VCP is through the Department of State and the annual appropriation for the Foreign Assistance Act. FY 1980 funding is for $2,000,000, of which $150,000 is provided directly to WMO by the State Department. The remaining $1,850,000 is administered by the Department of Commerce.

Global Atmospheric Research Program

The Global Atmospheric Research Program (GARP) is an international effort under the United Nations' World Meteorological Organization (WMO) and International Council of Scientific Unions. The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67, to be the lead agency in coordinating United States participation in the World Weather Program of WMO, which includes GARP.

GARP undertakes two basic types of observational experiments, regional and global. Regional experiments, such as GATE, acquire data needed to understand smaller scales of motion and how they affect the large-scale global circulation. Global experiments, such as the Global Weather Experiment, collect the worldwide data sets needed to study the large-scale global motions and circulation that produce changes in weather over longer periods.

EXPERIMENTS AND ANALYSIS

- DOC $5,490,000; NASA ($2,700,00); NSF $6,165,000 ($8,350,000)

The primary efforts of United States agencies with respect to experimental programs of GARP will be to initiate the research phase of the Global Weather Experiment. This experiment (described in Chapter 1) is of limited duration and is based on recent technical and scientific advancements. The formal international observing period covered 12 consecutive months, a complete seasonal cycle. This formal period was preceded by a buildup period during which the satellites of several nations and various specialized observing systems were launched and tested along with the data processing systems and models.

The Global Weather Experiment has four basic objectives: (1) to obtain a better understanding of atmospheric motions for the development of realistic models for extended range forecasting, general circulation, and climate; (2) to assess the ultimate limit of predictability of weather systems of various sizes and time scales; (3) to develop new methods for assimilation of meteorological data in numerical weather forecast models, in particular for more effectively using satellite data in the models; and (4) to design an optimum composite global observing system for routine numerical weather prediction on a global basis. During FY 1981, DOC Global Atmospheric Research Program funds will be used to complete the data management and archiving activities, and to support a comprehensive research program based on Global Weather Experiment data.

NASA is performing evaluation tests on the operational temperature sounders, conducting the "Special Effort" to enhance Global Weather Experiment data, and analyzing the data which have been obtained from satellites and other special observing systems. The analysis of the SEASAT data will provide a basis to evaluate the use of sea-surface wind observations in numerical weather prediction even though these data were not available for the Global Weather Experiment Observing Period.

Selected cases will be chosen from the Special Observing Periods of the Global Weather Experiment for intensive analysis. These cases will be studied in detail, made self-consistent, and then used in diagnostic studies and for verification of model forecasts.

The Department of Defense operates the Joint Typhoon Warning Center (JTWC) at Guam, which has responsibility to provide a continuous meteorological watch of all tropical activity north of the equator, west of the Dateline and east of the African Coast for potential tropical cyclone development. JTWC is planning to provide tropical storm information to the Japanese Tropical Warning Center in support of the upcoming regional tropical experiment (TOPEX).

From November 1978 to February 1979 the Coast Guard Cutter ACUSHNET (WMEC 167) deployed 16 U.S. drifting buoys and one Canadian drifting buoy in the South Pacific Ocean in support of the Global Weather Experiment. Additionally, the Coast Guard Cutter POLAR STAR (WAGB 10) launched eight U.S. buoys while in transit to the South Pacific during DEEP FREEZE 79.

In FY 1980 and FY 1981 NFS will continue to support research using GATE data. Many GATE research projects have been successfully completed, and a gradual reduction of organized GATE research will take place. NSF will provide support for the processing, analysis, and interpretation of data collected during the Monsoon Experiment (MONEX). The National Science Foundation and the Department of Commerce will support research at universities and private laboratories using data from the Global Weather Experiment. Many grants will be funded jointly by NSF and DOC, with administration provided by NSF. Support for preliminary studies related to the Alpine Experiment (ALPEX) will be provided by NSF. The field phase of ALPEX is scheduled for early FY 1982.

NSF will provide continued support for several International Decade of Ocean Exploration (IDOE) programs studying large-scale, long-period dynamics in the Pacific, Atlantic, and Southern Oceans.

ATMOSPHERIC MODELING AND SIMULATION.

- DOC ($10,484,000); NASA ($3,000,000) NSF $2,645,000 ($3,050,000)

The physical laws which govern the behavior of the atmosphere and oceans must be better understood and expressed in mathematical terms to provide continued improvements in weather forecasting and in the understanding and prediction of climatic events. DOC conducts a major research program to accomplish this at Geophysical Fluid Dynamics Laboratory (GFDL). Through the use of advanced digital computers, mathematical models are developed to simulate the behavior of the entire interacting ocean-atmosphere-earth cryosphere. This research is a major user of regional, synoptic, and global data provided by programs such as the Global Atmospheric Research Program, the Global Weather Experiment, and the Severe Environmental Storms and Mesoscale Experiment, and by weather satellites. By constructing physically precise models of the earth's system, GFDL will be able to simulate the behavior of geophysical phenomena reaching from the surface of the earth (boundary layer) up to the mesosphere and from the ocean's surface down to the deep ocean currents and extending from short-term events affecting a single city to long-term events leading to climatic change. Increasing emphasis is being placed on investigating seasonal and interannual climate evolution and the sensitivity of climate to human activities (e.g., carbon dioxide).

The NASA-Goddard Modeling and Simulation Facility is systematically evaluating the performance of the remote temperature sounding system on TIROS N. This evaluation involves comparison of operationally retrieved temperature profiles derived from infrared and microwave radiance measurements with collocated radiosonde temperature profiles, and generation of direct, physical inversion temperature profiles and comparison of these profiles with radiosonde temperature profiles and operational retrievals. The evaluation also will attempt to determine exactly what the effect or impact on forecast accuracy is for each of the following: satellite soundings; satellite-derived winds; special observing systems such as constant-level balloons, buoys, aircraft observations, etc. The evaluation will center on the data from Special Observing Period I (SOP-I) and will include approximately 20 case studies. This will be done by utilizing the various data mentioned to initialize a general circulation model and comparing the resulting forecast with the observed state of the atmosphere.

Goddard also is collaborating with NOAA and the University of Wisconsin to produce enhanced data sets for specific case studies within the Global Weather Experiment data set. Extensive modeling and simulation studies utilizing the Global Weather Experiment data will be undertaken to verify model improvements, simulate new sensor performance, determine the sensitivity of the forecast to errors in observation and in model physics, and to improve our understanding of atmospheric processes.

NSF supports studies of the global and regional atmospheric-oceanic system. Many of these studies combine numerical modeling and observational analysis and interpretation. During FY 1980 and FY 1981, emphasis will be on initial studies of regional and global numerical simulations using data from MONEX and the Global Weather Experiment. The long-term objective is to further understanding of the physical processes that affect weather and climate in order to improve the accuracy of weather forecasts and climate simulations. NSF-sponsored efforts include: improving and validating a detailed air-sea boundary layer model using GATE data; investigating the physics and energetics of monsoon development and the interaction of the monsoon with middle latitude disturbances using MONEX and Global Weather Experiment data; developing and testing methods of incorporating small-scale weather features in large-scale numerical models; investigating the physical processes that affect climate and climate change; and examining atmospheric responses to sea-surface temperature anomalies and other perturbations.

GLOBAL MONITORING AND CLIMATE

● DOC ($4,230,000); DOD ($3,700,000); NSF $320,000 ($1,450,000)

The overall goals of the monitoring and climate program are to determine the natural and human-induced causes of climate change; to determine the concentrations and properties of atmospheric trace elements and particles in the earth's atmosphere in regions remote from local sources; to understand the effect of changes in trace constituent concentrations and properties on global weather and climate; and to predict, through analytical studies and model development, the likely changes in global weather and climate resulting from the effects of human activities.

The DOC climate research program builds directly upon the Global Weather Experiment. In the early phases, many activities are inseparable and equally essential for both programs. Development and testing of models that accurately simulate the annual cycle and preparation of data sets are examples. Efforts will gradually become more distinct. Timely collection and processing of data from selected special observing systems deployed during the Global Weather Experiment will be continued, e.g., tropical, Arctic, and Southern Hemisphere buoys. Data sets for climate research that include after-the-fact compilations of specialized precipitations, ice and snow, solar and earth radiation, and oceanographic data will be completed and made available.

Other DOC efforts in the climate research program will include program planning; the conduct of analyses and experiments to determine the predictability of climate; the formulation and validation of models of the physical climate system, in particular of ocean-atmospheric coupling; and the determination of the sensitivity of models to alternative formulations, combinations of observed data, and possible changes in current atmospheric composition, surface conditions, and radiative forcing. The program will also further technological transfer of the Special Observing Systems, developed and used during the Global Weather Experiment.

NSF supports a variety of global monitoring efforts. As part of the International Decade of Ocean Exploration (IDOE) program, scientists working with the North Pacific Experiment (NORPAX) and another group of scientists working in the equatorial Atlantic will study long-period, large-scale ocean-atmosphere coupling. Special efforts are being made in NORPAX to monitor the North Pacific Ocean and atmosphere. IDOE also supports the International Southern Oceans Studies (ISOS), which monitor oceanic transports through the Drake Passage. The Division of Polar Programs at NSF supports a number of global monitoring and climate studies at the all-year-round U.S. Antarctic Stations (McMurdo, South Pole, Palmer, and Siple). In addition to the daily synoptic weather observations at the four stations, climate change indicators, trace elements, and atmospheric pollutants are monitored. Additional support of research includes climate-related processes, such as air-sea-ice interactions, katabatic winds, solar/weather relationships, and ice crystal formation.

The Department of Defense has numerous programs which support indirectly the World Climate Program even though their primary goal is related to the study of environmental factors effecting military operations and equipment. Studies of the upper ocean variability and air-sea-ice interaction are being funded by DOD in conjunction with NSF, NOAA, and others. Additionally, DOD is a major participant in the support of the National Oceanographic Satellite System. DOD activities support several interagency-funded studies as a part of NORPAX, INDEX, etc. The studies are primarily aimed at understanding the physical nature of the upper oceans and the air-ocean interface.

Systems Design and Technological Development

INSTRUMENT DEVELOPMENT

- DOC ($6,915,000); NSF $50,000 ($300,000)

The DOC program includes developing new and improved methods of obtaining satellite data and using these data more effectively in environmental monitoring, prediction, and warning. The purpose is to improve understanding of physical processes in the atmosphere, on land, and in the oceans using the unique capabilities of satellites to provide the basic data. The satellite's vantage point in space provides the capability to obtain data coverage in both time and areal extent not achievable by other practical observational techniques or systems. Developmental activities use universities and industrial groups through contracts and grants for satellite-related research. Close coordination is maintained with related NASA and DOD research and development programs.

Major DOC emphasis is on the development of improved techniques to measure the distribution of temperature, water vapor, and other constituents in the atmosphere from satellites. Users of these data require improvements in resolution (both horizontal and vertical), accuracy, and coverage. Part of this improvement program is a laboratory spectroscopy study of atmospheric gases to obtain better quantitative data on their radiative properties in order to improve the accuracy of satellite temperature soundings. The operational sensors on the current satellites and on the next generation of improved satellites are based on sensors and concepts developed by this program in past years. The ongoing program is designed to improve the current use of satellite sensor data and to prepare for operational use of the next generation of sounding instruments.

The National Center for Atmospheric Research (funded by NSF) is developing the "Safesonde" upper-air sounding system. It is designated for improved accuracy over the Rawinsonde system. NCAR is also developing the Micro Global Horizontal Orbiting Sounding Technique (Micro GHOST). It is a balloon-borne, satellite-communicating instrument package that will provide a variety of in-situ meteorological measurements.

BUOYS

- DOC ($8,792,000); NSF $395,000 ($110,000) DOT ($609,000)

DOC-NOAA operates 14 deep-sea moored data buoys and two moored buoys in the Great Lakes from which there are observations of atmospheric pressure, air and water temperatures, wind speed and direction, sea conditions, and subsurface measurements. Existing buoys were deployed as operational buoys to provide needed environmental data. The continuing engineering program seeks to develop systems to measure and report additional parameters, improve component reliability, and reduce the costs of operation. Special buoy systems are developed for specific programs, such as those carried out by GARP and energy development and recovery programs in the oceans.

NSF and DOC-NOAA emphasis in future development is on drifting and ice buoy systems; remote sensing of the lower atmosphere from buoy platforms; water quality measurements; and improving meteorological sensors, wave measurements, and subsurface profilers. Most of these developments will have direct application to the WWW. NSF is supporting deployment of buoys for the International Southern Oceans Studies (ISOS).

The U.S. Coast Guard provides personnel to support the Department of Commerce-NOAA Data Buoy Office (NDBO) in developing, operating, and evaluating data buoy systems. Coast Guard cutters and aircraft provide operational support to deploy, service, and retrieve buoys built for test or operational purposes. Through 1979, Coast Guard communications facilities had been used to relay data from buoys to the NDBO. By 1978 all East Coast buoys were converted to satellite relay, and on October 1, 1979, the remaining 12 West Coast buoys were similarly converted, so that Coast Guard data relay support is no longer required.

RESEARCH AND DEVELOPMENT SATELLITES

- DOD ($2,000,000); NSF $400,000

Funds for DOD are principally in support of the development of the technology for the National Oceanographic Satellite System, vital for determining the nature of the critical air-ocean interface.

The NSF is supporting the Advanced Very High Resolution Radiometer System at McMurdo which serves as the satellite communication link for Antarctic meteorological data transmission.

SUPPORTING RESEARCH AND TECHNOLOGY

- NASA ($33,100,000)

NASA will continue to develop new sensors using both passive and active remote-sensing techniques to achieve greater sensitivity, higher resolution, and greater accuracy. Evaluation of sensor performance will continue through the analysis and interpretation of the data. These efforts are intended to extend our capabilities for observing environmental parameters. Among the parameters of interest are: areas of rainfall (over land and oceans); snow and ice cover; soil moisture; surface temperature; vertical distribution of temperature, pressure, and moisture; ozone and other trace constituents; and vertical distribution of winds. The focus of this research is to establish remote-sensing capabilities to observe atmospheric and surface properties which will be useful for meteorological and climatological applications.

Upper Atmosphere

NASA will initiate a coordinated global observation system for long-duration simultaneous measurements of stratospheric parameters to evaluate the variability of the upper atmosphere and its response to perturbations. NASA will continue to focus on monitoring the nitrogen-oxygen and halogen-oxygen chemical cycles for their effects on ozone. This work will be supported by balloon flights and sounding rockets and space shuttle flights.

Global Weather

NASA will study and develop improved remote sounders to meet operational requirements and analyze Global Weather Experiment data for diagnostic and forecast model verification purposes. Numerical prediction models will be improved to assimilate satellite observations more readily, to simulate the physics of the atmosphere more realistically, and to incorporate more accurate and efficient numerical computation techniques.

Air Quality

NASA will continue to develop active and passive remote sensors for measuring global and/or regional air quality and to apply such measurements to the development of models that can assess human impact or the atmospheric environment. These activities include modeling, data analysis, laboratory studies (including determination of key chemical kinetic reaction rates), field measurements, and development and evaluation of key sensor technology.

Climate

Climate modeling, analysis, and sensitivity studies will also be undertaken to examine the mechanisms for climate change and the sensitivity of the climate system to changes in the boundary conditions. Steady-state and zonally averaged models will also be developed and used in climate studies to identify those parameters which are most sensitive. Models to utilize space-acquired data will be dev loped to aid in assessing climate predictability.

Climate data sets will be assembled from conventional and satellite sources. Data will be processed, screened, quality checked, corrected, cataloged, and archived for use. Data sets such as sea ice, cloudiness, radiation budget, ozone abundance, and precipitation are expected to be assembled to serve as the basis for climate studies.

Special studies on aerosols, radiation budget, air-sea interactions, and cryospheric processes will be continued. These studies are intended to gain insight and understanding of the physical processes involved, to make connections between climate variables, to develop parameterizations for models, and to aid in future sensor development.

4. Fiscal Summary

The United States has active and planned FY 1980 and FY 1981 activities in all major areas of the World Weather Program--World Weather Watch, Global Atmospheric Research Program, and Systems Design and Technological Development. Funding by various Federal agencies in the three areas is summarized below. Values shown indicate expected outlays for FY 1980 and amounts requested in the President's budget for FY 1981. Funding is categorized as either direct (specifically in support of the World Weather Program) or indirect (primarily for other agency needs, but also fulfilling a World Weather Program need).

Summary of U.S. funding for World Weather Program in FY 1980 and FY 1981 (in thousands of dollars)

MAJOR ACTIVITIES		FY 1980 Direct	FY 1980 Indirect	FY 1981 Direct	FY 1981 Indirect
WWW Implementation	DOC		82,578		85,935
	DOS	2,000		2,000	
	NASA		32,400		36,200
	TOTAL	2,000	114,978	2,000	122,135
GARP	DOC	5,448	14,446	5,490	14,714
	DOD		4,100		3,700
	NASA		6,800		5,700
	NSF	8,861	11,730	9,130	12,850
	TOTAL	14,309	37,076	14,620	36,964
Systems Design & Technological Dev.	DOC		16,701		15,707
	DOT		464		609
	DOD		1,200		2,000
	NASA		26,600		33,100
	NSF	1,299	350	845	410
	TOTAL	1,299	45,315	845	51,826
Totals by Agency	DOC	5,448	113,725	5,490	116,356
	DOT		464		609
	DOS	2,000		2,000	
	DOD		5,300		5,700
	NASA		65,800		75,000
	NSF	10,160	12,080	9,975	13,260
GRAND TOTAL		17,608	197,369	17,465	210,925

Appendix

LIST OF ACRONYMS AND ABBREVIATIONS

ACARS--ARINC-Communication, Addressing and Reporting System
AIDS--Aircraft Integrated Data System
AMTEX--Air Mass Transformation Experiment
APT--Automatic Picture Transmission
ARINC--Air Radio Inc.
ASDAR--Aircraft to Satellite Data Relay
AVHRR--Advanced Very High Resolution Radiometer
DCS--Data Collection System
DOC--Department of Commerce
DOD--Department of Defense
DOS--Department of State
DOT--Department of Transportation
ERB--Earth Radiation Budget (experiment)
ERBSS--Earth Radiation Budget Satellite System
ESA--European Space Agency
FAO--Food and Agriculture Organization
FGGE--First GARP Global Experiment
GARP--Global Atmospheric Research Program
GATE--GARP Atlantic Tropical Experiment
GDPS--Global Data Processing System
GFDL--Geophysical Fluid Dynamics Laboratory (NOAA)
GMS--Geosynchronous Meteorological Satellite
GOES--Geostationary Operational Environmental Satellite
GOS--Global Observing System
GTS--Global Telecommunication System
HALOE--Halogen Occulation Experiment
HIRS--High Resolution Infrared Radiation Sounder
HRPT--High Resolution Picture Transmission
ICSU--International Council of Scientific Unions
IDOE--International Decade of Ocean Exploration
IGOSS--Integrated Global Ocean Station System
IGY--International Geophysical Year
INDEX--Indian Ocean Experiment
IOC--Intergovernmental Oceanographic Commission
ISOS--International Southern Oceans Studies
ITOS--Improved TIROS Operational Satellite
LIMS--Limb Infrared Monitoring of the Stratosphere
METEOSAT--Meteorological Satellite
MONEX--Monsoon Experiment
MSU--Microwave Sounding Unit
MTS--Main Trunk Circuit
NASA--National Aeronautics and Space Administration
NAVAID--Navigational Aid
NCAR--National Center for Atmospheric Research
NMC--National Meteorological Center (NOAA)
NOAA--National Oceanic and Atmospheric Administration

NORPAX--North Pacific Experiment
NOSS--National Oceanic Satellite System
NSF--National Science Foundation
POLEX--Polar Experiment
RAMOS--Remote Automated Meteorological Observing Station
RBSN--Regional Basic Synoptic Networks
RMC--Regional Meteorological Center
RTH--Regional Telecommunication Hub
SCOR--Scientific Committee on Ocean Research
SEM--Space Environment Monitor
SMMR--Scanning Multichannel Microwave Radiometer
SMS--Synchronous Meteorological Satellite
SOP--Special Observing Period
SSU--Stratospheric Sounding Unit
TCLBS--Tropical Constant-Level Balloon System
TIROS--Television Infrared Observing Satellite
TOMS--Total Ozone Mapping Spectrometer
TOVS--TIROS Operational Vertical Sounder
TWOS--Tropical Wind Observing Ships
UN--United Nations
UNEP--United Nations Environment Program
VAS--VISSR Atmospheric Sounder
VCP--Voluntary Co-Operation Program
VISSR--Visible and Infrared Spin Scan Radiometer
WAMEX--West-African Monsoon Experiment
WCP--World Climate Programs
WHO--World Health Organization
WMC--World Meteorological Center
WMO--World Meterological Organization
WWW--World Weather Watch

*U.S. GOVERNMENT PRINTING OFFICE: 1980