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METEOROLOGY IN THE LESS DEVELOPED COUNTRIES

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I. INTRODUCTION

Meteorology today stands on a new threshold. Over the past twenty years there have been revolutionary advances in technology, notably the development of the meteorological satellite and the high-speed electronic computer, and in the scientific understanding of the atmospheric processes that determine weather and climate. These advances have already made possible improvements in meteorological services. For example, the first step in the preparation of modern weather forecasts and warnings is the hemispheric analysis and prognosis of the development and movement of wave-like undulations in the rivers of air aloft which meander around each hemisphere in the predominantly west to east flow. Trends in such flow patterns aloft profoundly affect the development and movement of storms and precipitation at the surface. Analyses on a complete hemispheric scale are needed in order to avoid rapid deterioration of the prognoses which results from eastward propagation of boundary conditions when analyses include only a portion of the hemisphere. Computer processing of data using the basic equations of motion in numerical form is producing more accurate upper-air prognoses for the entire northern hemisphere in less time than formerly required for manual analyses and prognoses for the western portion of the northern hemisphere alone. The many advances such as this have given scientists confidence that within reach may be the ability to make reliable long-range weather predictions of as much as two weeks ahead. Also, these advances will

make possible the exploration of the feasibility of large-scale weather modification and even control.

These developments have encouraged nations of the world to cooperate in an international program in meteorology to improve the capability of the existing international system and to seek to achieve the new scientific goals that scientists believe are now possible. There is already a long tradition of international cooperation in weather matters. Atmospheric movements know no national boundaries, and what happens in the atmosphere over one nation affects the atmosphere in distant parts of the world. Moreover, no single nation can observe and collect comprehensive data about the atmosphere everywhere over the globe. And so the nations of the world need to cooperate in meteorology.

A four-point program for the peaceful uses of outer space to be developed under United Nations auspices was proposed by President Kennedy in 1961. One part of the program called for an international cooperative effort in weather forecasting and atmospheric research. Resolutions embodying the four-point program have been unanimously approved by the U.N. General Assembly. Plans for an international meteorological program, including a World Weather Watch, a program of General Circulation Research, and a program of Scientific Education and Training, are now being prepared by the World Meteorological Organization (W.M.O.) and its member nations. Today, worldwide expenditures for meteorology amount to more than a billion dollars annually, and incremental expenditures for the World Weather Watch

are expected to amount to about $100 million annually to be shared by all nations.

Many member nations of the W.M.O., particularly the United States, strongly support the establishment of the World Weather Watch. At the request of President Johnson in 1964, the Secretary of Commerce established the Interagency Committee for International Meteorological Programs (ICIMP) to bring federal departments and agencies concerned with international activities and programs in meteorology into closer consultation and cooperation. This Committee recommended to the President in January 1966 that the United States provide full support to an international program in meteorology which would include the development of a World Weather Watch and the conduct of a comprehensive program of research on the global atmospheric system. Participation by the U. S. in these programs would be directed toward the achievement of three primary goals: (1) improvement of U.S. weather services; (2) achievement of a capability to make long-range weather predictions and explore the feasibility of climate modification; and (3) promotion of economic growth and technological development in the emerging nations.

The World Weather Watch is envisaged as a system for observing, communicating, and processing global weather data adequate to meet both the the needs of atmospheric scientists and the operational needs of the nations of the world.* The initial phase to be accomplished during the

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* Fourth Report on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space - August 1965, Secretariat of the WMO, Geneva, Switzerland

W.M.O. financial period 1968-1971 will be a program of utilizing existing equipment, techniques and procedures to greatly improve the present international weather system; this phase is of primary concern in this study. During and following this phase will be a program of developing and gradually introducing new technology. While the details have not yet been worked out, the general concept for the World Weather Watch in the 1968 to 1971 time period has been agreed upon. For instance, certain minimum observational network sensing requirements must be met for the World Weather Watch to be an effective universal system. The need for upper-air observations twice-a-day is generally accepted.

A fundamental issue is how the World Weather Watch will be implemented in its initial phase, the 1968 to 1971 time period, particularly in the less developed countries. Implementation is in principle the responsibility of individual countries. It is in the less developed countries that major gaps exist in the observation and communication networks, that meteorological services are generally at a low level, and that funds for improvement of meteorological services are most scarce. The World Weather Watch will offer nations opportunities for greatly improving their meteorological services capabilities, primarily related to forecasts and warnings, through more extensive data coverage, utilization of the latest technology, and eventually a better understanding of the general circulation of the atmosphere. So that the emerging nations may contribute to the World Weather Watch and utilize its meteorological products, new and upgraded facilities and technical assistance will be required. For this reason, the Agency for

International Development (A.I.D.), in cooperation with the Environmental Science Services Administration (ESSA), has undertaken a study of weather services and their benefits in the less developed countries in order to support planning by the U.S. and the W.M.O. for the World Weather Watch and to explore possible needs for foreign assistance in the meteorological field.

The three principal objectives of the study are: (a) to examine what development benefits may be expected to accrue to the less developed countries from participation in the World Weather Watch and from improved national weather services in general; (b) to estimate the magnitude of such investments as may be desirable; and (c) to assess the available options for funding World Weather Watch requirements in the less developed countries.

The following chapter gives the general conclusions and recommendations of the study. The remainder of this report provides a more detailed discussion. Certain of the information presented was obtained from a study of South America, principally Brazil. A separate report entitled Meteorology in Brazil: A Case Study contains more detailed information. Drawing from this South American experience, careful extrapolations to the less developed countries in general were made. Brazil, being a large country in several stages of economic development and encompassing a wide range of geographic and climatic conditions, lent itself as a model for such analysis.

II. CONCLUSIONS AND RECOMMENDATIONS

1. The Need for Assistance

The United States and other countries stand to gain very substantially from the World Weather Watch in terms of aggregate benefits to many weather-sensitive activities over the next decade. However, certain minimum improvements must be made to existing meteorological facilities in the less developed countries to make the World Weather Watch an effective global system during the 1968-1971 time period as there are major gaps in the meteorological observation and communications networks and a generally low level of meteorological services. Additionally, other improvements should be made to ensure that the less developed countries derive direct benefits from the World Weather Watch.

These World Weather Watch improvements in the less developed countries in the four-year period, 1968-1971, have been estimated in this study to cost about $43 million. Twenty-one million dollars would be for capital costs, $12 million for an average of two years" operations, and $10 million for training and technical experts. Total foreign exchange costs are estimated at about $26 million; the balance of $17 million is in local costs. Of the foreign exchange costs, it is estimated that foreign assistance must be provided for some $21 million.

Near-term benefits to the less developed countries from the World Weather Watch will generally not justify their giving priority attention to World Weather Watch investments, although long-term benefits are likely to be substantial. Active participation by these countries in the World Weather Watch, which is essential if the system is to become

operational, will therefore require financial assistance by the developed countries.

Recommendation: That the U.S. assume an appropriate share of the foreign exchange costs in the less developed countries, possibly $10 million, with other developed countries providing the balance.

2. Individual Country Responsibilities

Implementation of the World Weather Watch will be the responsibility of individual countries as agreed in the W.M.O. The value of the World Weather Watch to a country and the need for a country to contribute data to the global system must, therefore, be fully understood by each country.

Recommendation: That the W.M.O. encourage and assist each developing country in the preparation of a four-year plan for improved meteorological services which should take into account the needs for World Weather Watch improvements during the implementation period, 1968-1971.

The less developed countries are likely to provide little toward necessary foreign exchange costs because meteorological services will have to compete for scarce resources. However, the developing countries will be making an important contribution if they assume all of the estimated $17 million in local costs associated with the World Weather Watch.

Recommendation: That the less developed countries be encouraged to pay for all appropriate local costs as a matter of general principle.

3. Establishment of Priorities

Implementation of the World Weather Watch as a global system requires the filling of major gaps in meteorological observation and communications networks and the development of data processing centers. Questions can be

expected to arise in various countries and regions as to which improvements in meteorological services are most important, what should be done first, and which improvements require special assurances of funding support.

Recommendation: That realistic, generally agreed priorities for the World Weather Watch be established as precisely as possible and continually updated to assure that foreign assistance as well as local funding will produce an effective global system. This will assure that external assistance will not be dissipated in low priority uses, leaving critical gaps in the system as a whole for which additional funds will be needed.

4. Continuing Operating Responsibilities and Costs

After 1971 there will be continuing operating and maintenance costs estimated at about $6 million per year in the less developed countries, representing about 30 percent of total capital investments for World Weather Watch improvments during 1968 to 1971. The less developed countries should plan toward maintaining an appropriate organization, trained staff and financial support for operating an effective, continuing meteorological service system after 1971. However, they will need external financial assistance on a continuing basis unless significant benefits begin to be realized. For this to occur, the investments directly related to the World Weather Watch will not suffice. More localized data networks and weather services than the World Weather Watch provides will need to be developed. Interpretation and dissemination capabilities will need to be considerably expanded to provide timely, useful forecasts and warnings. Also, as the general level of economic and social development improves, there will be more significant and widespread opportunities for the application of weather information.

Recommendation: That these continuing operating responsibilities and the need for expanded investments in analysis and interpretation capabilities, dissemination capabilities, and the users' services receive appropriate attention in the meteorological plans of developing countries and the plans for the World Weather Watch.

5. Multilateral Assistance

In view of the global nature of the World Weather Watch, multilateral assistance appears to have many advantages for funding purposes. The integrated nature of the World Weather Watch requires that many critical gaps be filled. The aggregate of benefits to all nations will be substantial. Reliance on normal bilateral assistance would probably not meet the minimum requirements of the World Weather Watch.

Technical assistance through the U.N. Development Program should be used to the extent possible for training and technical experts. In addition, it appears desirable to establish a new multilateral arrangement especially for the World Weather Watch. A voluntary fund administered by the W.M.O. to which the U.S. and other nations would contribute has been proposed by the W.M.O. and appears appropriate as a means of providing the bulk of the assistance required for basic improvements required by the World Weather Watch. Such a fund could be tailored to the special funding requirements of the World Weather Watch; for instance, provision could be made for funding some operational costs. Arrangements might be made for contributions in kind as well as in dollars. A voluntary fund would stimulate contributions from developed nations, would heighten the international character of the program, would be conducive to a rationally coordinated investment in the system

and in its operation, and would strenghten the W.M.O., which has the key role in the program. Contributions by the U.S. to such a fund could be justified both on the basis of the aggregate developmental benefits to the less developed countries and the U.S. national interest in having a World Weather Watch which is global and effective.

Recommendation: That the U.S. encourage the formation of a suitable multilateral assistance program and participate fully in its execution.

6. Bilateral Assistance

The U.S. has provided a relatively small amount of bilateral assistance, mainly technical assistance, for meteorological programs in the less developed countries in the past. Bilateral assistance could be used to complement the meteorological investments made through a voluntary multilateral fund, if established, in particular countries and regions where the social and economic benefits warrant. Bilateral assistance is especially appropriate in countries like Brazil which are developing rapidly and where the social and economic benefits of meteorological investments can be readily recognized. Bilateral assistance where needed might appropriately concentrate on upgrading facilities, on institutional development, and on interpretation and dissemination of meteorological information for a growing body of users. Meteorology can be considered as an infrastructural element in country planning and may in many cases be a promising investment for regional programs.

The role of U. S. bilateral assistance in support of the World Weather Watch will depend on the degree of support for the voluntary

multilateral fund and will possibly be limited because of competing priorities among development projects, because priority investments in meteorology may not always be directly related to the World Weather Watch, and because there are many less developed countries for which A.I.D. provides no assistance or minimal assistance. Bilateral assistance by other nations may be similarly limited.

Recommendations:

(1) That A.I.D. bilateral assistance play a larger role in the meteorological field.

(2) That A.I.D. country and regional programming consider the possibilities for meteorological components in major programs and projects such as agriculture and hydrology.

(3) That the Military Assistance Program take into account World Weather Watch needs where it is appropriate.

7. Regional Cooperation

In the World Weather Watch program new technological developments in computers, satellites, communications, etc., can be exploited by all nations at a minimum overall cost due to the minimizing of redundancies in data collection and processing efforts. For instance, the centralized processing of basic meteorological data covering large areas can be done by high-speed digital computers with greater speed and accuracy and at far less cost than by manual methods in each country.

Regional cooperation can be a very important part of the World Weather Watch. The W.M.O. plans for the World Weather Watch already

include a number of Regional Meteorological Centers which will provide services to a number of nations. These Centers can provide more efficient weather services to the countries involved and serve as a model of the advantages of expanded regionalism.

Recommendations:

(1) That regional cooperation be given high-priority consideration in the design of improved meteorological services, and in the provision of foreign assistance support, so that economies of scale may be realized.

(2) That W.M.O. Regions take the initiative in consolidating national plans into regional plans which take into account World Weather Watch input requirements and output products.

(3) That the W.M.O. assign to each W.M.O. region a staff of at least one member to assist in updating of plans and coordinating implementation of the World Weather Watch within the region.

(4) That the U.N. Regional Economic Commissions be kept fully informed of World Weather Watch plans.

8. Benefits

The extent of social and economic benefits to the less developed countries from improvements in meteorological services is an important issue because of the competition for scarce resources. But, the value to development of meteorological investments is more difficult to assess than many other types of investments. Meteorological and climatological information contribute social and economic value in a broad variety of weather-sensitive processes and activities by making possible better planning and operational

management decisions. However, in the less developed countries, meteorological benefits are generally potential or long-range because such benefits depend upon, among other things, adequate dissemination and the readiness and ability of users to make use of the meteorological information.

The World Weather Watch offers nations opportunities for greatly improving their meteorological capabilities, primarily related to forecasting, through better and more extensive data, analyses and prognostics over large areas, and eventually a better understanding of the general circulation. Individual countries will obtain improvements through such a global system more quickly and at less cost. The most immediate benefits derivable from improved meteorological services associated with the World Weather Watch in many of the less developed countries appear to be those related to air transportation -- improved flight planning, fewer diverted flights, less holding time for landings, and improved traffic control. The largest economic benefits in the long run, however, are likely to be in the agricultural sector. Potential savings related to the use of weather information for more efficient irrigation operations; for more efficient applications of chemicals used for fertilizing and control of plant diseases and insects; and for reduced spoilage in crop harvesting and storage are estimated to total many times the cost of improved meteorological services.

The World Weather Watch will also develop basic meteorological systems where they are now inadequate, help to build up a climatological data base, and provide a focal point and more scientific base for

meteorology throughout the world which will help to win wider appreciation of the economic and social importance of meteorology. The World Weather Watch will accelerate the development of weather modification techniques.

The economic and social benefits of meteorology will in many instances differ greatly between countries and in the same country between economic sectors due to such factors as differences in the levels of economic development and in climate. Therefore, different levels of expenditures for meteorological services may be appropriate between different countries and different economic sectors. Within a country, selectivity in the design of meteorological services is important in order to meet the most important needs.

Recommendation: That the less developed countries explore possible social and economic benefits from improved meteorological services and consider investing in such services along with general investments in weather-sensitive activities.

9. Investments Apart from the World Weather Watch

There may in some cases be investments in meteorology which at a given time are of higher priority to a given country than investments directly related to the World Weather Watch. Improved climatological services in particular can contribute benefits early in the economic development process through better planning decisions in land use, selection of types and varieties of crops, river valley development, etc. However, in many of the less developed countries climatological data are inadequate.

Another type of meteorological investment which may be important is agro-meteorological research.

Recommendation: That the concept of the World Weather Watch be broadened to include complementary efforts to meet special meteorological needs in developing countries. For example, good climatological and hydrological substation programs could be established and World Weather Watch data processing facilities could be used on a time-available basis for storing climatological data, performing routine analyses, and compiling such data.

10. The Need for Starting Improvements Now

Although many of the benefits of improved meteorological services will not be realizable in the immediate future, some meteorological improvements should begin now in the developing countries. Investments for the World Weather Watch can begin to build quality, basic meteorological systems in developing countries which will require a number of years and which can then more adequately meet increasing demands. For example, as long as five years will be required to train more adequate staffs of meteorologists and technicians and to develop the organizational base for the improved meteorological services. An even greater lead time is required for collecting good climatological and hydrological data, information which can be of great value in furthering economic development.

11. Organization

In some nations there is more than one meteorological service. These should be adequately coordinated in order to more efficiently

utilize resources and to facilitate the implementation of the World Weather Watch.

Recommendation: That adequate coordination arrangements between meteorological services within a given country be made a condition for multilateral and bilateral assistance to assure its effectiveness.

12. Manpower and Training

Adequate numbers of qualified people are not available to operate present meteorological facilities in the less developed countries, and World Weather Watch improvements will require even more qualified people. Retention of scientifically and technically qualified personnel in meteorology is essential; in many cases, greater recognition and remuneration may be necessary to assure this. Also, training will be a key problem in successful implementation of the World Weather Watch.

Recommendation: That the retention of qualified personnel and the programs at all levels from observers to research scientists be given priority attention.

13. Equipment Design

Meteorological instruments and communications equipment designed for standard use in temperate regions may not be suitable for use in tropical climates because of rapid deterioration; such environmental differences must be considered. Equipment used in less developed countries must be reliable because skilled maintenance personnel are scarce and foreign exchange is limited for replacement parts and spares. For the same reasons, the most sophisticated equipment available may not be the most appropriate.

Recommendation: That the W.M.O. consider possible needs to design instruments and equipment specifically adapted to special climatic and technological environments peculiar to some of the less developed countries.

14. Expendables

Any assistance provided to developing countries for the World Weather Watch must take into account the operational costs. Expendables for upper-air stations are a large component of World Weather Watch operating costs and are almost wholly foreign exchange costs. Few upper-air stations in the less developed countries take the standard two observations per day because of this expense.

Recommendation: That the developed countries assist the less developed countries in obtaining expendables through reduced costs or direct financial assistance.

15. Utilization of Advancing Technology

The World Weather Watch is composed of components from technologies in different stages of growth. Some components can be expected to be of a transient nature while others will represent lasting investments. It is essential that these differences be recognized and identified so that opportunities for improvements and cost reductions associated with some of the new technologies can be realized. Satellite communications, in particular, should be given greater attention, for communications is a

major problem in implementing the World Weather Watch, and present communications involving most less developed countries are wholly inadequate.

Recommendation: That attention be given to the various technological options available for implementing the World Weather Watch; in particular, that additional communications cost comparisons be made in the light of plans for satellite telecommunication facilities.

16. APT Unit

The Automatic Picture Transmission (APT) unit which enables countries to obtain direct readouts of pictures from meteorological satellites deserves special consideration. The APT unit provides pictures of current weather systems as delineated by cloud patterns, each picture covering about 1,000 miles square. An APT unit can assist in forecasting, particularly in areas where data collection is inadequate, such as ocean and coastal regions. However, benefits from APT units will be slight unless a meteorological service can adequately analyze, interpret and disseminate the information obtained.

Recommendation: That countries which may be interested in the APT unit be provided with technical plans for building and installing low-cost units, and advice concerning collateral meteorological service requirements.

III. THE WORLD WEATHER WATCH

The World Weather Watch will consist basically of an observation network, a communications network, and data processing centers. While the details have not yet been worked out, the general concept for the World Weather Watch in the 1968 to 1971 time period has been agreed upon.* (See Appendix for a more complete description.) The World Weather Watch will utilize existing equipment, techniques and procedures to improve the present international weather system. New technology will be developed and gradually introduced. The World Weather Watch will be but one part of a global meteorological program which will also include General Circulation Research and Scientific Education and Training.

The observation network will consist of upper-air stations on a grid no greater than 600 nautical miles over land areas,** a synoptic surface station network of approximately four times this density, and ocean stations vessels and moving ships for ocean areas. The upper-air stations are to have both radiosonde and wind tracking capabilities (this combination is termed rawinsonde) and to make observations twice a day. Many of these facilities already exist, others are yet to be established (See Fig. 1). The main needs are for some additional upper-air stations on islands and in certain remote land areas, expendables for upper-air stations in less developed countries, and greatly expanded ocean coverage.

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* Fourth Report on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space - Aug. 1965, Secretariat of the W.M.O., Geneva, Switzerland; W.M.O. Executive Committee XVIII Session, 1966, Geneva, Switzerland.

** Computer experiments have shown that there are limits beyond which thinning out of the upper-air observational network leads to rapid loss of effectiveness of the system. See a preliminary Assessment of the World Weather Watch Observational Network for the Period 1968-1971, by M. A. Alaka and F. Lewis (in preparation for publication as an ESSA Technical Memorandum, Weather Bureau Techniques Development Laboratory). An approximately 600 n. mi. grid over land areas has been agreed to; nevertheless, some variations and trade-offs in the numbers and locations of observing points are possible.

CURRENT AVAILABILITY OF DATA

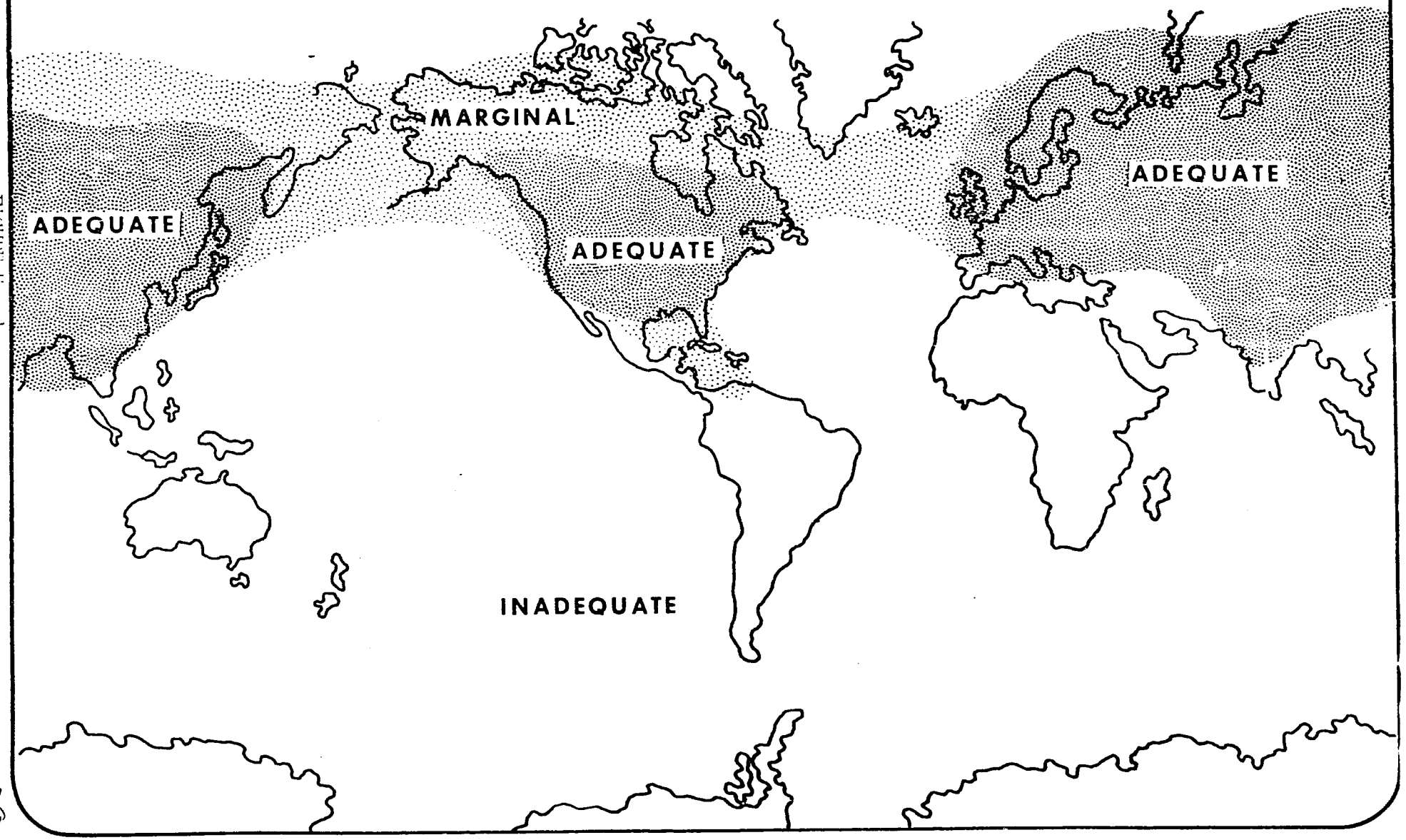

FIGURE No. 1

The main communications network will consist of a high-speed, reliable trunk connecting the three World Meteorological Centers at Melbourne, Moscow, and Washington with Regional Telecommunications Hubs in a number of regions. Regional Telecommunications Hubs will then be tied to individual nations which in turn must make national collections. The goal is to collect all data at World Meteorological Centers withine one and one-half hours after the observations. Improved communications at all of these levels are needed, particularly in the less developed areas.

The data processing system will include the three World Meteorological Centers and a number of Regional Meteorological Centers. The functions of these Regional Meteorological Centers will be decided by each regional grouping of countries which is interested. Such regional centers can provide more efficient weather services through economies of scale.

While full implementation of the World Weather Watch as planned for the 1968 to 1971 time period and outlined above would be desirable, there will be obstacles to full implementation. In the less developed countries major gaps and inadequacies exist in the observing and communications networks, and funds for improvement of meteorological services are scarce. These problems will be discussed in the next chapter.

The processed data that will be the output products of the World Weather Watch will be sent to each country over the same communications system used to gather the data. The products will consist of analyses, prognoses, and graphical depiction charts prepared at World Meteorological

Centers using the latest scientific computer techniques supplemented by the assistance of experienced meteorologists. A typical list of such products is given in Table 1; gradually, additional products will be added. In most cases these products will be sent by facsimile and issued twice daily. Figure 2 indicates a possible layout for a facsimile chart. The products will be an important basis for the preparation of localized forecasts and warnings and weather information bulletins by each national service. The quality of the output products will depend upon the data inputs and only as improvements are made in the observational system in sparse data areas will the output products for these areas be of reasonable quality.

The developed countries will be able to make efficient use of the output products of the World Weather Watch; however, the less developed countries will not unless they have adequate analysis, interpretation, and dissemination capabilities. The Regional Meteorological Centers will provide some of these capabilities to a group of less developed countries.

Table 1

WORLD METEOROLOGICAL CENTER
OUTPUT PRODUCTS

IDENT. NO.	PRODUCT	CONTENT	AREA	VALID PERIOD	CYCLE	FORM	METHOD OF PRODUCTION	DISTRIBUTION
	ANALYSES							
RMC-1	Surface Chart	Isobars, fronts, large-scale cloud and weather patterns	Global	0 Hrs.	12 Hrs.	Graphic & digital	Machine	Regional Communications Centers and/or RMC's for relay to Nations
RMC-2	500 MB Chart	Contours, isotherms, isotachs, vorticity, vertical velocity	"	"	"	"	"	"
RMC-3	200 MB Chart	Contours, isotherms, isotachs, jets	"	"	"	"	"	"
RMC-4	50 MB Chart	" " " "	"	"	"	"	"	"
RMC-5	Satellite Mechanalysis	Cloud cover	"	"	24 Hrs.	"	"	"
RMC-6	Satellite IR Data	Cloud cover, height of tops	"	"	"	"	"	"
	PROGNOSES							
RMC-7 -8 -9 -10	Surface Chart	Isobars, fronts, large-scale cloud and weather patterns.	"	12 Hrs. 24 36 48	12 Hrs	"	"	"
RMC-11 -12 -13 -14	500 MB Chart	Contours, isotachs, vorticity, vertical velocity, maximum wind streams	"	12 24 36 48	"	"	"	"
RMC-15	200 MB Chart	Contours, isotachs, maximum wind streams	"	24	"	"	"	"
RMC-16	Medium Range Forecasts	Daily isobars & fronts, Mean isobars & upper air contours, temp. & precip. anomolies	"	5 days	3 per week	"	"	"
RMC-17	Long Range Forecasts	Mean upper air contours, temp. anomoly, precipitation	"	30 days	2 per month	"	"	"
RMC-18	Storm Alerts	Warnings on position and movement of storms sighted by satellite data	"	As needed	As needed	Alpha-Numeric	Not Applicable	"

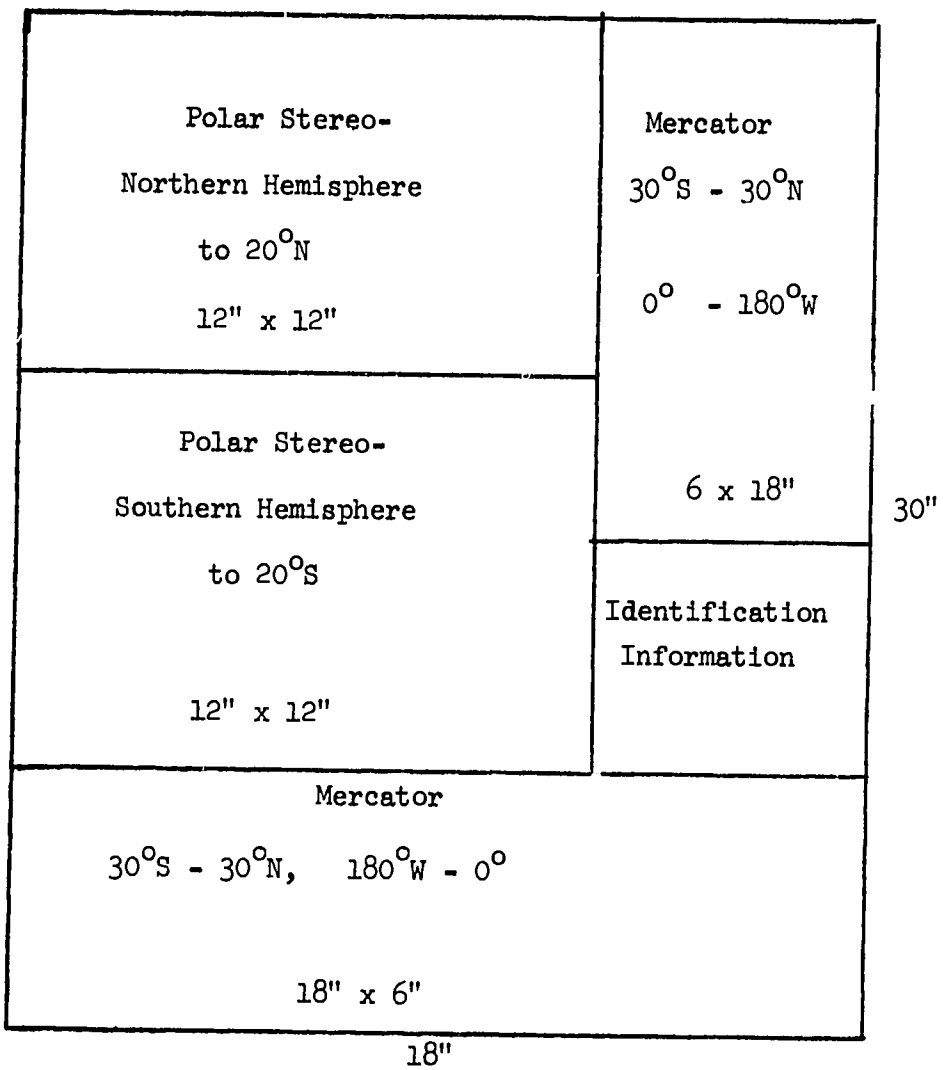

Figure 2. GLOBAL CHART FACSIMILE LAYOUT

METEOROLOGICAL SERVICES IN THE LESS DEVELOPED COUNTRIES

The meteorological services in the less developed countries are generally of a low level as compared with services in developed countries. Not only will some new facilities be needed, but many facilities will undoubtedly have to be considerably upgraded in order to provide reliable, timely data for the World Weather Watch. The density of observations, particularly upper-air observations, is often very inadequate. Meteorological communications in the less developed countries are rarely by point-to-point radio-teletype link; while some single sideband radio is used, communications are mostly by commercial telegraph which sometimes results in delayed or even lost data. There are often too few technicians to make inspections and to maintain equipment. Services to users may consist of only one forecast per day, primarily for the most populated areas with no updating of forecasts and no warnings. These examples indicate that if the World Weather Watch is to be successful, many improvements will have to be made in numerous aspects of the meteorological services in the less developed countries.

Attention is drawn to several different aspects of meteorology before further discussion of the status of meteorological services in the developing countries. Figure 3 is a schematic of the elements of a weather service. A principal distinction is that between climatology, the description and analysis of historical weather data, and the forecasting of weather. The World Weather Watch is primarily concerned with forecasting although the

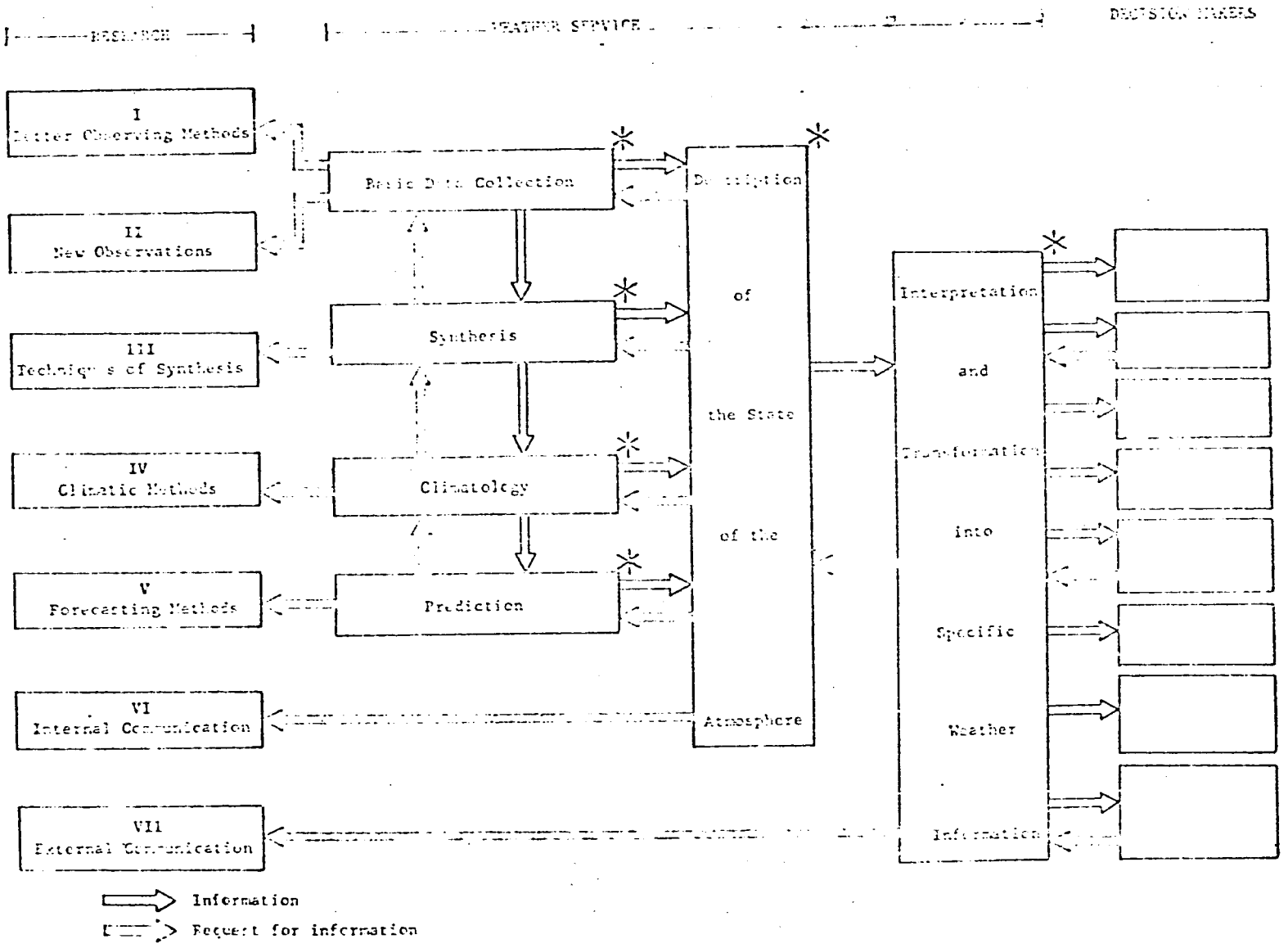

Fig. 3: Schematic of the elements of a weather service

/1/ The solid arrows indicate requests for better information. Some of these requests are operational or within the "state of the art." Listed on the left side of this chart are seven classes of research and development for requirements beyond the "state of the art."

/2/ Adapted from "Weather Information, Its Uses, Actual and Potential," by R. R. Rapp and R. E. Huschke; The RAND Corporation; Memorandum RM-4083-USWB, May, 1964.

expanded data networks will provide data for climatological services as well. Another distinction in meteorology is that between global or macro-scale and more localized data and resulting analyses and prognostics. In many cases, the localized information may be of as much or more importance to an individual country, although the global analyses and prognostics will be a useful starting place for any forecast. Meteorological services may also be distinguished between the economic sectors that they support such as agriculture, aviation, and hydrology. A still further distinction is that between operations, that is supplying specific planning or forecasting information, and research. Meteorological investments may concentrate on one or many of the above aspects of meteorology.

Some of the problems of meteorological services in the less developed countries are now discussed, particularly those problems associated with the World Weather Watch. The discussion is generalized with some examples taken from the study in Brazil; some of these problems may be fairly universal among the less developed countries although others may apply in only a relatively few.

There are many gaps in meteorological observations in the less developed areas of the world and particularly in the Southern Hemisphere. The filling of many of these gaps and the assurance that the observational data gets wide distribution are principal objectives of the World Weather Watch. Upper-air data are highly essential for the fulfillment of the operational and research goals of the World Weather Watch, and the

principal observational gaps are for upper-air data. In general, the surface data required for the World Weather Watch can be met by using existing networks. However, refurbishing of equipment may be necessary at some surface stations, as was found in the case of Brazil. Even where upper-air or surface observation stations exist, observations may not be taken as often or at the times desired for the World Weather Watch. Many surface synoptic stations take only two or three of the standard four observations each 24 hours. Only a relatively few upper-air stations in the developing countries take the standard two observations per day. These upper-air observations are relatively expensive and require foreign exchange for the purchase of expendables (rawinsondes and balloons). Some possible solutions to this particular problem are: (1) providing engineering technical assistance for the design of rawinsonde instruments that can be manufactured in at least some of the less developed countries; (2) obtaining broader support within the less developed countries for the upper-air observation program; (3) purchasing of the expendables through a World Weather Watch pool that has large purchasing power; and (4) providing expendables through multilateral or bilateral assistance.

While the observation stations required by the World Weather Watch will not include a climatic and hydrologic substation program in the less developed countries, it will provide more and better surface and upper-air data at a larger number of stations than previously available. Countries will probably eventually want a substation network for climatological studies at least ten

times the density of the surface synoptic network. Fortunately, these substations cost far less than synoptic stations.

Another important source of observational data for less developed countries will be meteorological satellites. The E.S.S.A. Automatic Picture Transmission (APT) satellite is part of the World Weather Watch data system from which many countries can benefit immediately, particularly those countries with relatively sparse data networks. APT receivers installed at large centers could obtain much data on cloud and weather systems. These data would effectively supplement other data sources, particularly for areas where data are now sparse such as off the coasts of many countries. The cost of a manual tracking, commercial APT unit is less than $20,000, and one may be readily constructed within a country for less than $10,000.

Weather data must be collected rapidly and analyzed promptly for timely and effective presentation and use of weather forecasts and warnings. Aside from the large number of observational stations required, the greatest unmet requirements of the World Weather Watch in the less developed countries are centered around inadequate communications. In Brazil and probably in many other less developed countries, most of the meteorological data are handled by the national telegraphic system and by the military communications system. Neither gives weather reports high priority handling, and the reports are often delayed or even lost in transit. In many less developed countries, the demand for communications is rising rapidly, and meteorological communications requirements will represent an increasingly smaller

proportion of the total demand. Meteorological communications should make use of general communications systems as they are developed to a maximum practical extent and not concentrate on a single purpose system. Of course, adequate priorities must be assured for rapid communication of meteorological data. Meteorological communications between countries is often by means of broadcasts. In some cases, the present broadcast facilities are relatively low powered and need improvement or replacement by point-to-point communications.

It should be noted that observation and communications equipment designed for operation in developed countries may sometimes be inappropriate in less developed countries. For example, the most sophisticated types of electronic gear may be more difficult to maintain and require more foreign exchange costs for replacement parts and spares. Some equipment may be adversely affected by the climatic conditions in tropical areas.

The services to users provided by meteorological services in the less developed countries are in general very limited. At present, generalized forecasts are prepared only once daily in many less developed countries for selected cities and regions. These forecasts are usually given very limited dissemination, sometimes only in the form of printed bulletins distributed by messengers. The general forecasts often are not updated when new weather patterns differ nor are specific warnings issued. Forecasts for aviation are issued more frequently and are updated but usually not to the degree required by international standards. The World Weather Watch will provide

many products which are basic to the preparation of localized forecasts and warnings.

Services to users would be improved by providing direct communications links between local forecast offices and radio stations or other news media for rapid dissemination of weather information. Greater use of meteorological services would benefit from a public education and information program which would help create a demand for such services. However, before there is substantially greater provision of services to users, basic improvements in data and communications networks should be made and forecasting abilities should be improved with more scientific methods to increase their qualtiy and their acceptance by users as the basis for specific actions.

Another of the problems facing the less developed countries in improving their meteorological services is connected with personnel. The opportunities for well-qualified scientific and technical personnel in the meteorological field are often sharply limited because of inadequate recognition and renumeration. For instance, the average forecaster in Brazil receives about one-sixth the salary of U.S. forecasters, which provides a rather low living standard compared with many other job opportunities in the less developed countries requiring college-level training. Well-trained meteorologists and electronic technicians often leave the meteorological field for the rapidly growing technological firms in many of the developing countries or even to more developed countries. At the observer level too, there is often a problem of keeping qualified and dependable personnel.

Training will be a key problem in successful implementation of the World Weather Watch. There are generally inadequate numbers of qualified people to operate present facilities and World Weather Watch improvements will require even more trained people. Trained observers, climatologists, meteorological technicians, instrument maintenance personnel, electronic technicians, forecasting meteorologists, and administrators are all needed. Training programs for these people are inadequate and must be established or upgraded. Not only must new personnel be trained, but some retraining of present personnel will be needed. For example, the implementation of the World Weather Watch will require retraining of many forecasters in the scientific concepts used to prepare World Meteorological Center prognoses, so that these products can be better understood. Eventually, in order to provide better services to special groups of users, individuals will have to be trained in the dual disciplines of agricultural meteorology, hydrometeorology, etc.

In order to provide an overall comparison of the many requirements for improved meteorological services with available resources, each developing country should be encouraged to develop, if it has not already, a four- or five-year plan for improved meteorological services. The planning should include not only meteorological improvements to be implemented as a part of the World Weather Watch program during 1968-1971, but also continuing funding for operation and maintenance of the improved system after 1971.

In Brazil, an appraisal of the continuing operating requirements associated with implementing not only the World Weather Watch but also other planned improvements in the national meteorological services showed that operating and maintenance costs can be expected to double by the end of the next five years.

Regional cooperation can be a very important part of the World Weather Watch. In general, it is of growing importance in A.I.D.'s programs. The concept of Regional Meteorological Centers which will provide services to a number of nations will provide more efficient weather services as well as serve as a model of the advantages of expanded regionalism. There are also other ways in which countries might appropriately cooperate in their own regions in meteorology. Regional cooperation should be given high priority considerations in the design of improved meteorological services.

V. SYSTEM COSTS

Costs for the World Weather Watch are estimated in this chapter. The technical requirements of the World Weather Watch have not been defined in detail, but the general concepts of the system have been agreed upon. The requirements in less developed countries must, of course, be related to existing capabilities in individual countries including observing facilities, communications facilities, human resources, and training facilities. It has been assumed in this study that there are some minimum improvements which must be made to existing meteorological facilities in the less developed countries to make the World Weather Watch an effective global system which can be realistically implemented in the 1968 to 1971 time period. It has also been assumed that additional improvements must be made to insure that the less developed countries derive direct benefits from the World Weather Watch. Based upon these assumptions, order of magnitude costs for the World Weather Watch improvements in the less developed countries in the four-year period 1968 to 1971 have been estimated. These estimates help to put the World Weather Watch program in the less developed countries into perspective and provide a basis for estimating potential capital and technical assistance needs. The costs are incremental to the current level of expenditures for meteorological services and include only those costs that are directly related to the World Weather Watch. These cost estimates are summarized in Table 2 and described in detail in the Appendix. The total cost has been estimated at $43 million. The

Table 2

Summary of Estimated Costs in Less Developed Countries
(Millions of U.S.$)

	Capital Costs	Annual Operational Costs	Total*
Observations			
Upper-air	2.8	2.5	7.8
Surface	0.9	-	0.9
Total	3.7	2.5	8.7
Communications			
Regional Telecom. Hubs	4.5	0.5	5.5
National Met. Centers	2.7	0.4	3.5
Internal	4.1	0.9	5.9
Total	11.3	1.8	14.9
Analysis and Interpretation			
Regional Met. Centers	3.0	0.5	4.0
National Met. Centers	2.5	0.5	3.5
Total	5.5	1.0	7.5
Dissemination and User Services	-	0.8	1.6
Training	-	-	4.6
Technical Experts	-	-	5.7
Grand Total	20.5	6.1	43.0

*It is assumed that there is a phased implementation during FY 1968-1971 and that an average of two years of annual operating costs are incurred.

largest element of the cost is communications at $15 million. Observations at $9 million, and analysis and interpretation are $8 million. Training and technical experts together are an additional $10 million. These costs include capital and operating costs. In estimating the latter it is assumed that there is a phased implementation during 1968-1971 and that an average of two years of annual operating costs are incurred.

The types of costs are shown in Table 3. Of the total of $43 million, $21 million would be for capital costs, $12 million for operational costs (an average of two years), and $10 million for training and technical experts. Total foreign exchange costs are estimated at $26 million, leaving $17 million in local costs. Fourteen million dollars of the foreign exchange costs would be for capital equipment (rewinsonde equipment, teletypewriter equipment, etc.) and $5 million would be for operational costs including $3 million for upper-air sounding expendables (balloons and rawinsondes). Nearly all of the technical experts costs, or about $5 million, would be foreign exchange costs.

Some of the World Weather Watch Costs are more important than others. If the job of obtaining data for the World Meteorological Centers alone is considered, then only $31 million is necessary (See Table 4). However, if the less developed countries are to derive some benefit from the World Weather Watch and be interested in participating at all, then there are additional investments which are desirable, totaling about $12 million.

The estimated costs are shown by region in Table 5. The largest cost

Table 3

Estimated Costs by Type (Millions of U.S.$)

	Foreign Exchange Costs	Local Costs	Total
Capital Costs			
Equipment	14.0	2.0	16.0
Installation	-	4.5	4.5
Total	14.0	6.5	20.5
Operational Costs-2 years			
Personnel	-	5.6	5.6
Parts and Supplies	2.0	1.6	3.6
Expendables	3.0	-	3.0
Total	5.0	7.2	12.2
Training	1.8	2.8	4.6
Technical Experts	5.0	0.7	5.7
Grand Total	25.8	17.2	43.0

Table 4

Estimated Costs by Necessity (Millions of U.S. $)

Necessary	Foreign Exchange	Local	Total
Observations	5.8	2.9	8.7
Communications	8.9	6.0	14.9
Training	0.3	1.7	2.0
Technical Experts	4.3	0.6	4.9
Total	19.3	11.2	30.5

Desirable	Foreign Exchange	Local	Total
Analysis and Interpretation	4.3	3.2	7.5
Dissemination and User Services	-	1.6	1.6
Training	1.5	1.1	2.6
Technical Experts	0.7	0.1	0.8
Total	6.5	6.0	12.5

Table 5

Estimated Costs by Regions

	Observations		Communications		Analysis and Interpretation; Dissemination and User Services		Training	Technical Experts	Total
	Capital Costs	Operational Costs-2 yrs.	Capital Costs	Operational Costs-2 yrs.	Capital Costs	Operational Costs-2 yrs			
Latin America	2.0	2.4	3.4	1.1	1.3	0.9	1.6	1.7	14.4
Africa	0.8	1.3	4.3	1.4	2.3	1.5	1.5	2.2	15.5
Asia	0.9	1.2	3.7	1.1	1.9	1.2	1.3	1.8	13.1
Total	3.7	4.9	11.4	3.6	5.5	3.6	4.6	5.7	43.0

is estimated for Africa, but Latin America and Asia are only slightly less. The major differences are that Latin America requires the most stations and that Africa requires communications among the most countries. Costs have also been estimated by countries (See Table 6). The countries where the largest investments will be required are those where a number of new upper-air stations are required or where Regional Telecommunications Hubs and Regional Meteorological Centers will be located. While the cost estimates in this report may be fairly representative in the aggregate, breakdowns by country or region may be subject to many errors because the status and needs of individual meteorological services varies widely among countries and regions.

Implementation of the World Weather Watch is the responsibility of individual countries. Since the local costs are high, estimated at about $17 million, the developing countries will be making an important contribution if they assume all of the local costs. (Assuming that there are fifty major developing countries where improvements will be made, the local costs average out to about $350,000 per country for the four years.) However, the less developed countries are likely to provide little toward necessary foreign exhange costs because meteorological services will have to compete for the limited supply of foreign exchange usually available to them. Multilateral and bilateral assistance will therefore have to be provided for most of the foreign exchange costs if the World Weather Watch is to be implemented.

Table 6

Estimated Costs by Country[1]

	Number of Upper-air Stations[2] New	Augmented	Communications[3]	Costs[4] (Millions U.S. $)
Latin America				
Brazil	9	3	RTH	5.0
Argentina	0	5	sub-RTH	1.8
Venezuela	1	0	sub-RTH	1.2
Chile	3	0		1.2
Ecuador	2	0		0.9
Peru	1	1		0.8
Bolivia	1	1		0.8
Guatamala	1	0		0.5
Columbia	0	0		0.3
Uruguay	0	0		0.3
Other	0	3		1.4
Total	18	13		14.3
Africa				
Kenya	0	0	RTH	1.6
Algeria	0	2	sub-RTH	1.2
Nigeria	0	0	sub-RTH	0.9
Senegal	0	0	sub-RTH	0.9
U.A.R.	0	0	sub-RTH	0.9
Libya	2	0		0.9
Mali	1	1		0.8
Sudan	1	1		0.8
Somali Republic	1	0		0.7
Ethiopia	0	1		0.5
Other	0	14		6.4
Total	5	19		15.3
Asia				
India	0	0	RTH	1.6
Philippines	1	1	sub-RTH	1.4
Pakistan	0	1	sub-RTH	1.1
Thailand	0	0	sub-RTH	0.9
Indonesia	3	3		1.8
Saudi Arabia	2	1		1.2
Iran	0	1		0.6
Oman	1	0		0.5
Syria	0	0		0.3
Other	0	4		3.8
Total	7	11		13.1

1. The list of countries is not intended to be comprehensive.
2. Recommended by W.M.O.
3. RTH = Regional Telecommunications Hub
4. Capital costs, two years of operations, and technical assistance.

NOTE: Countries listed in descending order of estimated costs, except that countries with RTH's and sub-RTH's are listed first.

If it is assumed that a maximum of $2 million of foreign exchange costs worldwide will be provided by individual developing countries for the World Weather Watch in the 1968 to 1971 period, then assistance must be provided for about $24 million. Some assistance is already planned for South America by the U.N. Development Program, M.A.P., and A.I.D., amounting to an estimated $2.5 million in foreign exchange costs directly related to the World Weather Watch. In addition, the U.N. Development Program is providing about $300,000 total in Africa and Asia for Regional Telecommunications Hubs. Therefore, it is estimated that additional sources of foreign assistance must be provided for some $21 million in foreign exchange.

Developing countries may wish to make improvements in meteorological services not directly related to the World Weather Watch (e.g., climatology, agro-meteorological research). Such investments would be over and above the minimum World Weather Watch investments already discussed. In some cases, less developed countries might justifiably place a higher priority on these investments compared to World Weather Watch investments; this may be particularly true where climatological services could use improvement. The planned A.I.D. loan for meteorology in Brazil is an excellent example of improvements both related and unrelated to the World Weather Watch. The loan will help to upgrade 100 synoptic stations, more than required for World Weather Watch global analyses, but which are needed for more detailed local forecast purposes. Likewise, the planned communications system is more extensive than required by the World Weather Watch alone in order to

provide for the collection and distribution of observational data and forecasts within the country. In addition, the loan will support some meteorological research.

While this paper is concerned only with the less developed countries, mention should be made of certain "international" elements of the World Weather Watch. These elements have to do with ocean areas and islands. It is expected that these elements will be financed directly by the individual nations involved. This will clearly be the case with ocean station vessels. If it is decided that some ships belonging to less developed countries should be fitted out as "moving ships", then the question of assistance may arise. Islands belonging to less developed countries have already been included in cost estimates in this paper. It is expected that islands belonging to or under the jurisdiction of developed nations (e.g., Australia, New Zealand, U.K.) will be taken care of by those nations. The W.M.O. plans call for 13 new and 24 upgraded upper-air stations on islands. The total cost to developed nations for these islands is estimated at about $9 million for the upper-air stations and for single-sideband communications facilities.

The costs which have been estimated in this chapter have been based on many assumptions and uncertainties. It is often useful to have an idea of the sensitivity of these costs to certain changes in assumptions. A 20-percent change in upper-air station costs would affect total costs by $1.5 million. No operational costs were included for refurbished surface

stations since it was assumed that these stations are already operating at an appropriate level of expenditure. If, to insure satisfactory operation, budgets must be supplemented by $5,000 per station per year, the added costs are $2.2 million (almost entirely local costs). If it is assumed that for every upper-air station, three rather than four observation stations on the average require improved communications, estimated costs will be reduced by $1.5 million.

Only the first four years of the World Weather Watch (1968-1971) are considered in this paper. There will be continuing operating and maintenance costs in the less developed countries estimated at about $6 million per year. Also, additional World Weather Watch improvements will be made in ensuing years. In part, these improvements will be based on the introduction of new technology. Many of these improvements will occur in the less developed countries, particularly as they desire to make increased use of meteorological information and to make better use of the World Weather Watch products available to them.

VI. THE BENEFITS OF METEOROLOGICAL INFORMATION

Consideration of potential benefits is of key importance in this study. While some benefits are sure to be derived from improvements in national weather services, a less developed country must, in general, be convinced of the sufficiency of such social and economic benefits. Likewise, a foreign assistance project is generally justified on the basis of the social and economic benefits that will flow from it to the recipient country. Thus, the extent to which the less developed countries can benefit from improved weather services and can utilize improved meteorological products, and the relative priority of investment in weather services as compared with other areas of investment must be given careful attention. Determining the benefits of weather services is difficult because the benefits are often intangible, long-term, and not easily generalized among countries and among economic and social activities. In this study it was possible to identify and analyze only some of the more important facts derived from a broad treatment of the subject, together with a detailed study of several economic sectors in Brazil.

Weather, Climate, and Man

The effects of weather pervade the social and economic activities of a nation. Weather disasters related to hurricanes, floods, and drought provide dramatic evidence of some of the most devastating effects. Less dramatic and seldom newsworthy are the constant adjustments required of

individuals and industries in response to the ever-changing weather. The principal ways in which meteorological information may be of value are: (1) protection of life; (2) preservation of health, the promotion of safety, contribution to convenience and general well-being; (3) improved economic planning; and (4) increased efficiency in the production of goods and services. The accomplishment of these objectives and their attendant social and economic benefits depends on the existence of an efficient means of acquiring, processing, and communicating atmospheric information for the user, and on the readiness and ability of users to understand and make decisions on the basis of the information thus provided. Weather information (prediction and description) is useful only insofar as it leads to a decision to take a favorable course of action. Thus, the benefits of meteorological information to a less developed country are generally potential or long-range. These potential benefits will be realized increasingly as economic and social development proceed and the general educational level, communications, etc., improve. For example, more intensive aviation activities, use of increasingly sophisticated agricultural methods, and new river control systems will call for better weather services. The needs of each country for weather services will differ, of course, due to differences in climate and economic structure.

Climate and weather influence man's activities perhaps to a greater extent in the temperate areas than in the tropics because there are more frequent and extreme adjustments to make. Most of the developed countries

and several developing countries are in the temperate latitudes (e.g.: Argentina, Turkey and South Korea), but most of the developing countries are in the tropics. While the temperate-latitude countries may have more to gain from a better knowledge of the weather, such as the World Weather Watch can provide, the tropical countries will gain through such things as a better understanding of the intertropical convergence zone and its effect on tropical weather, better prediction of the beginning of the rainy season and of heavy rains, warning of the occasional cold air masses that push into the tropics, and better climatological data for land-use planning. The differences between tropical and temperate areas require that caution be exercised in comparing the benefits of weather information in a developed, temperate area with the benefits in tropical, less developed countries. Tropical areas, even when highly developed, will probably not utilize weather information to the same degree as in temperate areas. But, while weather services may never be as extensive for this reason, a given investment in weather services in tropical, less developed countries may have equal or greater benefits than an equivalent investment in a temperate area because of the present low-level of weather services, which suggests that the level of diminishing returns for such investments may not be reached soon.

Uses of Weather Information

Some of the major uses of meteorological information in the developing countries are listed in Table 7. This list is not comprehensive, but it

Table 7

General User Requirements for Meteorological Services

Operational Activities	Climatology	Forecast Period 0 to 48-hour	72-hour	Five-Day	Two-Week	1-3 Month Trends	Research
Agriculture							
Application of chemicals, fertilizers, herbicides, fungicides, pesticides, insecticides, etc.	X	X					X
Irrigating	X	X	X				X
Frost Protection	X	X					
Planting	X	X	X	X	X	X	
Harvesting	X	X	X	X	X		
Transporting and Marketing	X	X	X	X	X		
Drying and Storing	X	X	X				X
Land Use Planning	X						X
Crop Diversification	X					X	X
Hydrology							
Power Production	X	X	X	X	X	X	
Flood Control	X	X	X	X	X		
Water Supply	X	X	X	X	X	X	
River Valley Development	X						X
Aviation							
Route & Airfield Planning	X						X
Schedule Planning	X						
Preflight Planning		X					
Inflight		X					
Commercial Fishing	X	X	X	X	X	X	X

does give an idea of the broad impact of meteorology and the multiplicity of ways in which benefits can accrue. Three examples of user groups in the less developed countries which can benefit especially from weather services and which, to some extent, require contrasting types of weather services are aviation, agriculture, and hydrology. Aviation safety is very dependent on good meteorological services; the services required are generally current weather information and short-term forecasts covering large areas. (To date, most of the technical assistance given for meteorology has been related to aviation.) Agriculture is obviously greatly affected by weather, particularly at planting and harvesting time, and timely weather information disseminated to the farmer may help improve the efficiency of operations and reduce crop losses. Climatological information is particularly important for agricultural land use planning. Long-range forecasts, such as the two-week forecasts which the World Weather Watch may eventually provide, could also be especially valuable for agriculture. Realistic planning for the control and supply of water, including river basin development and the design of hydroelectric projects, requires extensive past meteorological data. The uses of weather information will be discussed in more detail later.

It is very difficult to demonstrate the benefits of meteorological services in any quantitative fashion. Meteorological information contributes social and economic value by making possible better planning and operational management decisions in many weather-sensitive activities. As previously

mentioned, many of the benefits will be long-range in the sense they will only be realized as the developing nations become more developed. Even in the U.S., efforts to demonstrate benefits quantitatively have been limited. In the less developed countries appropriate data are often difficult to obtain, especially data on weather related losses.

However, an attempt can be made at putting benefits and costs into perspective for a particular country, in this case Brazil. Brazil is a large country of 80 million people which presently spends about $2 million on weather services each year. These services are generally recognized as less than adequate. An improved weather service which would provide reasonable quality services to many possible users would cost at least an estimated $5 million per year. This would represent about 6¢ for each person, each year. This compares with nearly 60¢ per person currently in the U.S., but per capita income is 10 times higher in the U.S. $5 million would also be less than 0.1 percent of Brazil's total agricultural production. Adequate weather services, properly utilized, would probably be able to reduce costs and losses in agricultural production by at least this amount. One timely warning of a frost or a disease blight can save tens of thousands of dollars. Therefore, it would seem that aggregate benefits in agriculture and other areas could readily justify the modest investments required for improved weather services. Of course, the meteorological investments alone are not sufficient for many other conditions must exist, such as improved general education levels. While the above discussion

has been in terms of Brazil, the situation in many other less developed countries may be similar.

Benefits can depend to a considerable degree on the nature of the investments in meteorological services, particulary since these services are multi-functional, in that they serve many purposes. Varying degrees of emphasis may be given to climatology and forecasting; macro-scale and micro-scale meteorology; aviation, agriculture, and other sectors; collection of data and dissemination to users; and operations and research.

Benefits of the World Weather Watch

Investments in the World Weather Watch in the less developed countries will not necessarily make possible all of the benefits referred to in Table 7. But, the World Weather Watch offers nations a way in which to greatly improve their meteorological capabilities, primarily related to forecasting, through better and more extensive data, analyses and prognostics over large areas, and eventually a better understnading of the general circulation. The World Weather Watch will also develop basic meteorological systems where they are now inadequate, help to build up a climatological data base, and, very importantly, provide a focal point and more scientific base for meteorology throughout the world which will help to win wider appreciation of the economic and social importance of meteorology. The day of weather modification will be brought closer.

Benefits gained from investments in a particular less developed country will benefit not only that country, but also the U.S. and other

countries. Participation by less developed countries in the southern hemisphere in the World Weather Watch will eventually provide some direct operational benefits to the U.S. meteorological service. Also, U.S. users of international weather information, such as the Air Force and Navy, international air carriers, and certain U.S. shipping interests, will directly benefit. The U.S. will also benefit from the research efforts which will be associated with the World Weather Watch.

In some cases investments in meteorology can be identified which may at a given time be of higher priority than investments directly related to the World Weather Watch itself. Such investments should not be overlooked because they may be of relatively greater importance to a country. In particular, improved climatological services may be important to a less developed country because available climatological data for planning and research purposes often are quite inadequate. Climatological services can contribute early in the economic development process through better planning decisions in land use, selection of types of crops and varieties, river valley development, etc. Ideally, at least twenty years' data are required as a record base from which generalizations can be drawn. Such data can be accumulated by starting an expanded climatological network, along with basic synoptic networks.

* * * * *

Three economic sectors -- aviation, agriculture, and hydrology -- were selected as significant weather-sensitive areas for this study.

These and several other benefit areas are now discussed in more detail with examples drawn from Brazil.*

Aviation

Timely meteorological information is necessary for safe and efficient aviation operations. Domestic aviation is becoming increasingly important in some countries, for instance, Brazil and Peru. In fact, aviation transport in Brazil ranks second highest in the world in aircraft movements. As international air travel continues to grow, requirements for meteorological information services in support of aviation will grow rapidly. In the developed countries, the principal benefits to aviation from improved meteorological services are as follows, and it may be expected that developing countries will be able to benefit similarly:

a. Improved terminal forecasts with fewer holding delays and diverted flights;

b. Improved flight planning by use of upper-air winds and temperature forecasts with decreased flight time, less turbulence and more efficient fuel load planning;

c. More efficient air traffic control through better estimates of arrival times and improved scheduling of acceptance rates;

d. Greater safety due to improvement in forecasting, flight planning, and traffic control; and

e. More convenience through the completion of more flights on schedule with less discomfort enroute.

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* Meteorology in Brazil: A Case Study, A.I.D. and E.S.S.A.

Agriculture

Agriculture is the single most important economic sector in developing countries. Planning for land use, particularly diversification of crops and opening up new areas to agriculture, requires adequate climatological data. Agro-meteorological research is also needed. In many countries production is concentrated in just a few crops, often for export earnings; more stable economies dictate some diversification. In Brazil, for example, significant amounts of coffee acreage are being diversified.

The use of new varieties, better practices, farm machinery, and agricultural chemicals, including fertilizers, herbicides, pesticides, and insecticides, is growing rapidly. As the more sophisticated and often more weather-sensitive agricultural production techniques are introduced, more economic benefits from applications of weather services become apparent. Better use of available water with the help of improved weather information may also be of considerable importance.

Weather is a factor in the occurrence and spread of many agriculturally important plant diseases such as potato blight, tomato blight, black pod rot of cacao, and pineapple skin spot. Also, animal diseases and insect infestations are related to weather. More research needs to be done in tropical and subtropical countries to identify critical ranges and combinations of weather parameters related to epidemic outbreaks of such diseases or insects. After the meteorological event has been defined, is subsequently forecast, and warnings are issued, farmers can use various sprays and dusts for timely

control of the spread of the disease. Spraying or dusting as a mechanical routine without benefit of meteorological information can be uneconomical. In Brazil in 1965, 70 percent of the tomato crop in the Northeast was lost due to tomato blight; black pod rot fungus in Brazil in 1964-65 reduced the cacao crop by 25 percent from the previous season. The control of insects in cotton fields is important, and spraying and dusting operations are becoming common. Since rains soon after spraying or dusting can drastically reduce the effectiveness, the annual savings possible from timely weather information can be considerable. In Brazil there are more than 6 million acres of cotton under cultivation, and if the cost of even a single spraying or dusting operation in all of the cotton acreage were saved, it could amount to $15 or $20 million.

Weather information can sometimes improve the use of irrigation water. In southern Brazil, especially in the state of Sao Paulo, irrigation is widely practiced. At present, members of the large COTIA Cooperative in that area are encouraged to irrigate on a routine three to five-day schedule. It is estimated that 1,000,000 hectares of land are irrigated. Although the cost of irrigating varies considerably, the average unit cost for one irrigation has been estimated at about $5.50 per acre. If through the use of timely weather information a net savings could be made of only three unnecessary irrigations per season for only one-half the irrigated land, the savings could amount to $40 million per year, or about twenty times the present annual budgets of the Brazilian weather services.

Potential benefits to agriculture in the millions of dollars could also be realized through identification of the beginning of the "rainy season" in certain parts of the world, such as Northeast Brazil. These rains sometimes begin one or two months earlier or later than "normal". Plantings must be phased with the rainy season. Long-range forecasts, one to three months in advance, are needed but must await, in part, further research on large-scale fluctuations in the movement of the inter-tropical convergence zone. This research could be undertaken using data collected and processed in the World Weather Watch program.

Hydrology

In many countries river valley development is essential for future economic growth since these developments will provide electric energy, flood control, water supply, sanitation, irrigation, and recreation. Meteorological data are important for planning river valley developments and planning other hydrologic projects. Operational day-to-day meteorological information, including quantitative precipitation forecasts, are needed in flood forecasting, maximizing utilization of water, and the timing of irrigation.

Other Benefits

The reduction of losses due to natural disasters, such as hurricanes and typhoons, and the conservation of both the quantity and quality of natural resources may often be achieved with the help of meteorological information. The usefulness of weather warnings in reducing loss of

lives from natural disasters has been amply demonstrated. However, possible saving of lives through the use of warnings awaits development of effective warning systems which are often lacking in the less developed countries.

Meteorological services also contribute to the economy of operations and reductions in loss of lives at sea through improved weather forecasts and warnings for fishermen, ocean shippers, and coastal small-craft operators. Many of the more developed nations of the world now make available ship routing services to portions of the northern hemisphere, which enable ships to circumvent storms and reach port sooner with fewer losses. Similar services in the tropics and in the southern hemisphere could contribute significant savings.

VII. FOREIGN ASSISTANCE OPTIONS

Implementation of World Weather Watch improvements is in principal the responsibility of individual countries. In the less developed countries, as mentioned previously, major gaps exist in the observation and communications networks, meteorological services are generally at a low level, and funds for improvement of meteorological services are most scarce. The United States and other countries stand to gain very substantially from the World Weather Watch in terms of aggregate benefits to many weather-sensitive activities over the next decade. However, near-term benefits to most of the less developed countries from the World Weather Watch will not justify their giving priority attention to World Weather Watch investments. Active participation by these countries in the World Weather Watch, which is essential if the system is to become operational, will therefore require financial assistance by the developed countries.

In Chapter V, World Weather Watch improvements in the less developed countries were estimated to cost about $43 million, of which about $26 million is estimated to be foreign exchange costs. Of course, additional investments might be desired in the less developed countries to go beyond the minimum improvements and for investments not related directly to the World Weather Watch.

Since the less developed countries can be expected to provide little toward these necessary foreign exchange costs because meteorological

services will have to compete for the limited supply of foreign exchange usually available to the developing countries, the total cost of needed assistance is estimated at approximately $21 million over the initial four-year period, 1968-1971. The developing countries will be making an important contribution if they assume all of the local costs associated with the World Weather Watch, estimated at about $17 million.

The options for providing this needed foreign assistance, as well as for providing assistance for other improvements not necessarily directly related to the World Weather Watch, are now discussed. The options are:

A. Multilateral assistance could be provided through existing United Nations assistance programs, such as the U.N. Development Program.

B. Multilateral assistance could be provided through new multilateral arrangements.

C. Developed countries could provide normal bilateral assistance. Such assistance by the U.S. could be provided through A.I.D. on the basis of the contribution of meteorological improvements to the economic development of countries or regions or through the Military Assistance Program on the basis of national security. Normal country and regional programming procedures would be followed.

D. Individual developed countries might agree to pay certain costs as a unilateral action on the grounds that the facilities are needed to complete the World Weather Watch and fulfill certain national interests

of the donor country. In the U.S. this would probably require special authorization.

Assistance from a combination of these sources may be appropriate in particular countries or regions. For instance, a less developed country may pay for certain facilities, seek A.I.D. assistance for others, and seek technical assistance through the U.N. Development Program.

The four options for providing assistance to less developed countrie for the World Weather Watch have implications for the foreign assistance programs of the U.S., other developed countries, and international bodies. Foreign assistance, either bilateral or multilateral, implies a cost to the U.S. However, foreign assistance for meteorology will be only a small part of the total investment that the U.S. will make in the World Weather Watch; for example, the U.S. will be paying directly for the World Meteorological Center in Washington, for the Tiros Operational System, and the development of new technology. The options are now discussed in more detail.

Existing Multilateral Assistance Programs

The United Nations has provided assistance for meteorology through the U.N. Special Fund and the Expanded Program of Technical Assistance (E.P.T.A.) which are now combined into the U.N. Development Program (U.N.D.P.). In addition, the W.M.O. established a New Development Fund (N.D.F.) for the 1964-1967 period.

Special Fund projects must have an element of research or training; research in this context includes natural resources surveys, research institutes, and pilot projects. A project must fall within the framework of a consistent economic policy and it should contribute to the future development of the national economy, either through capital formation, through the opening up of natural resources or through the improvement of technical skills. Except in some special cases, it is the policy of the Special Fund not to finance projects requiring a contribution of less than $250,000. Governments receiving assistance are expected to make a substantial contribution to the total cost of the project, usually not less than a third and preferably not less than half. Ten Special Fund projects with the W.M.O. as executing agency have been approved to date, totaling $5.7 million. These projects, each in a different country, have included the expansion of meteorological and hydrologic service and the creation of research and training institutes.

U.N. Expanded Program for Technical Assistance (E.P.T.A.) supports economic development projects in the less developed countries. The scope of projects is broad, and technical advice, training, and fellowships are emphasized. E.P.T.A. does not normally provide assistance for direct equipment purchases except in some cases where specific equipment is needed in support of a mission of technical experts. U.N. Specialized Agencies, including the W.M.O., are utilized for project implementation. E.P.T.A. funding for projects being administered under the auspices of the W.M.O.

for 1961-62 was $1.1 million, for 1963-64 $1.8 million, and for 1965-66 $2.6 million.

The W.M.O. New Development Fund (N.D.F.) provides assistance for projects of a strictly meteorological nature and was set up in 1963 with an authorization of $1.5 million for the period 1964-1967. The utilization of N.D.F. is guided by the following stipulations. At least half of the resources should be directed towards the improvement of facilities, and particular attention should be given to meteorological equipment, telecommunication installations and data processing activities. Approximately 10 percent of the funds should be directed to support education and training activities, and 30 to 40 percent of the resources should be devoted to surveys and studies related to the planning of the World Weather Watch. It may be noted that the relatively small allocation to education and training is due to the fact that most of the W.M.O. activities in this field are covered by the U.N.D.P.

Assistance from the N.D.F. will terminate in 1967. Assistance from the U.N.D.P. has been limited to technical assistance, and a major policy change would have to be effected to permit funding capital projects or operations. Funds are limited and meteorological improvements for the World Weather Watch have to compete with many other projects. However, the U.N.D.P. might be able to provide a substantial portion of the assistance required for training and should be encouraged to do so; also, it could provide some funding for technical experts.

New Multilateral Arrangements

New multilateral arrangements established especially for the World Weather Watch would have the advantage that funds would be earmarked and implementation of the World Weather Watch would not be subject to the uncertainties which arise from competing priorities. The idea of a voluntary fund administered by the W.M.O. has recently been suggested and informally endorsed by several countries, including the U.S. The fund could be tailored to the special funding requirements of the World Weather Watch; for instance, provision would be made to provide for some operational costs. Arrangements could probably be made for contributions in kind as well as in dollars. A voluntary fund would stimulate contributions from other developed nations, would heighten the international character of the program, would be conducive to a rationally coordinated investment in the system and in its operation, and would strengthen the W.M.O. which has the key role in the program. Contributions by the U.S. to such a fund could be justified, both on the basis of the aggregate developmental benefits to the less developed countries and the U.S. national interest in having a World Weather Watch which is universal and viable.

Normal Bilateral Assistance Programs

The U.S. provides bilateral assistance through the Agency for International Development (A.I.D.), the Food for Peace Program, and the Military Assistance Program (M.A.P.).

The Agency for International Development (A.I.D.) provides both capital and technical assistance for broad programs of development in many of the less developed countries. Capital assistance is currently given almost exclusively with long-term, low-interest bearing loans. Technical assistance, usually in the form of grants, is provided for U.S. technicians and other advisors and for training in the fields of health, education public administration, community development, housing, industry and agriculture; the development of human resources is stressed. Under technical assistance, equipment and material can be provided to support the efforts of U.S. specialists or underwrite the development of institutions abroad to make the training programs more effective. Also, foreign nationals are brought to the U.S. for study.

In general, A.I.D. projects are considered in the context of a country's over-all development plan and priorities; projects must show reasonable promise of contributing to economic and social development and must be economically and technically sound. Operating costs are not generally funded under A.I.D. development assistance, and the Agency must be satisfied that the country will be able to support the activity once it is completed. In addition to economic development benefits, there might be political benefits to the U.S. from such bilateral assistance.

A.I.D.-funded projects of a direct meteorological nature have included ten projects in as many countries during the past ten years for a total U.S. expenditure of $1,257,000. For the most part, these projects have consisted

of the provision of a meteoeological consultant attached to A.I.D. Civil Aviation Assistance Groups to provide for the development of meteorological services for aviation and to assist in the over-all development of the meteorological services of the country involved. These projects have included training by the meteorological consultants and also have provided equipment necessary to provide meteorological services for both domestic and international air transportation. Projects of this type have been carried on in Brazil, Chile, Honduras, Panama, Greece, Thailand, Korea, and Viet Nam. Two other projects were in Costa Rica and Guinee. An A.I.D. loan is planned for Brazil, amounting to $2.2 million, which would substantially upgrade present facilities and would provide training.

The Food for Peace Program is carried out under Public Law 480, the Agricultural Trade Development and Assistance Act. The responsibilities for the program are shared by A.I.D., the Department of Agriculture, and other government departments. A.I.D. has a major responsibility for administering the overseas operation of this program, including its integration with other economic assistance extended by the United States. P.L. 480 has four titles of which two are of interest here. Under Title I, foreign countries buy American farm products with their own currencies instead of dollars. The foreign currencies realized from these sales are controlled by the United States and can be used, in turn, for many purposes, several of which are: to pay some of the overseas costs of American embassies and other United States Government programs; to be lent, under certain

conditions, to United States private enterprise overseas, or to be turned back to the government of the cooperating country as loans or grants for economic development. Title IV authorized long-term supply and dollar credit sales aggreements with foreign governments, providing for the financing of export sales of U.S. agricultural commodities. Although Title IV is a dollar repayment program, the sale of the agricultural products in the recipient country earns local currencies that are available for such social and economic development programs as are mutually agreed upon by the host government and the Government of the United States. Funds in the amount of $515,000 have been utilized under the P.L. 480 program to carry out meteorological projects in Israel, India, and Pakistan of mutual interest to the Weather Bureau and the countries.

The Military Assistance Program(M.A.P.), administered by the Department of Defense, helps to safeguard the independence of certain nations resisting Communist encroachment. As military establishments in these nations require meteorological services, M.A.P. funding has been utilized to a limited extent to assist in providing equipment and training. Such assistance is justified, of course, on the basis of military requirements. M.A.P. currently has programmed assistance for some new upper-air stations in South America.

The U.S. has provided a relatively small amount of assistance for meteorological programs in the less developed countries in the past. While some technical assistance has been provided, there has been relatively

little assistance for facilities and equipment.

A.I.D. bilateral assistance could play a larger role in the meteorological field. It would have to be provided on the basis of normal country and regional programming procedures, however, unless major policy changes were made. Meteorology should be considered as an infrastructural element in country planning, and the possibilities for meteorological components in major country programs such as agriculture and hydrology should be considered. Meteorology may in many cases be very appropriate for regional programs. The role of U.S. bilateral assistance in support of the World Weather Watch will possibly be limited because of competing priorities among development projects, because priority investments in meteorology may not always be directly related to the World Weather Watch, and because there are many less developed countries for which A.I.D. provides no assistance or minimal assistance. Bilateral assistnace by other nations may be constrained in similar ways. Because the integrated nature of the World Weather Watch requires that many critical gaps be filled and because some assistance for operational costs may be necessary, normal bilateral assistance would probably not be adequate for the minumum requirements of the World Weather Watch program. The primary criteria for investments to meet these minimum requirements may well be that of creating an effective and universal system.

The Food for Peace Program should be considered for providing local monies in "excess currency" countries to support meteorological research, and possibly even the installation of capital equipment and the operation

of meteorological facilities.

M.A.P. assistance is provided for national security reasons and therefore special conditions would have to exist for its use. Since the World Weather Watch will be of considerable value to our military and our national security, M.A.P. should be encouraged to take into account World Weather Watch needs where it is appropriate.

Special Bilateral Programs

To go beyond the assistance options described above, new Congressional authority may have to be sought. A major reason that might be advanced for new authority is that earmarked monies are needed to assure a global and effective World Weather Watch; reliance on economic developmental benefits to less developed countries and other standard criteria may not assure this result. World Weather Watch investments in developing countries will directly benefit the U.S. and there will be aggregate and long-range developmental benefits to the less developed countries -- considerations which are not always given highest priority in bilateral assistance decisions.

Conclusions

In view of the importance of the international meteorological program to the U.S., the potential benefits to the developing nations, and the necessity for foreign assistance in order that the system be global and effective, it is essential that the U.S. and other developed nations provide assistance to less developed countries for meteorological improvements.

A voluntary fund administered by the W.M.O. to which the U.S. and other nations would contribute appears to be a most promising means for providing a substantial protion of the assistnace required for basic improvements required by the World Weather Watch. The World Weather Watch is a global system and its many parts must fit together into this system if it is to be effective. Centralization of management and funds should be conducive to this end. The U.N. Development Program could supplement the voluntary fund. If most of the basic needs of the World Weather Watch were taken care of by a voluntary fund, bilateral assistance could be used to complement the meteorological investments made through the voluntary fund in particular countries and regions where the social and economic benefits warrant. Bilateral assistance would be especially appropriate in countries like Brazil where the country is developing rapidly and the social and economic benefits of meteorological investment are more readily recognized. Bilateral assistance could concentrate on upgrading facilities, on institutional development, and on interpretation and dissemination for users.

The World Weather Watch is a concept which, potentially, encompasses many things. In this paper, the concept has been used in the restrictive sense of an internation weather system in which certain minimum or basic improvements to the present system would assure an effective global system from which all nations would derive benefits. The technical requirements of the World Weather Watch have not yet been defined in detail, so that questions can be expected to arise in various countries and regions as to which improvements in meteorological services are most important, what should

be done first, and which improvements require special assurances of funding support. Unless realistic, generally agreed priorities are established as precisely as possible, the assistance sources which are anticipated will be sufficient for the basic World Weather Watch may go into projects of lesser importance. Thus, critical gaps may be left in the system as a whole for which additional funds will have to be found.

Appendix: DESCRIPTION AND COSTS OF WORLD WEATHER WATCH ELEMENTS

The description of the World Weather Watch in Chapter III and the cost estimates in Chapter V are discussed in more detail in this Appendix. The assumptions relating to the World Weather Watch requirements and costs are given.

The World Weather Watch has not as yet been defined in detail, but the general concepts of the system have been agreed upon.* The requirements of the World Weather Watch in the less developed countries are, therefore, subject to various interpretations. The assumption is made in this study that there are some minimum improvements which must be made to existing meteorological facilities in the less developed countries to make the World Weather Watch a global and effective system which can be realistically implemented in the 1968 to 1971 time period. The assumption is also made that there must be some additional improvements to ensure that the less developed countries derive direct benefits from the World Weather Watch.

The principal elements of the World Weather Watch in the less developed countries are listed in Table 1. The types of costs that may be associated with each element are listed in Table 2. Order-of-magnitude costs have been estimated for these elements in the less developed countries for the 1968 - 1971 time period. These costs are incremental to current expenditures for meteorological services.

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*Fourth Report on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space-August 1965, Secretariat of the W.M.O., Geneva, Switzerland; W.M.O., Executive Committee XVIII Session, 1966, Geneva, Switzerland.

Table 1

SYSTEM ELEMENTS

Observation

- Upper-air
- Surface

Communications

- Regional Telecommunication Hubs
- National Meteorological Centers
- Internal

Analysis and Interpretation

- Regional Meteorological Centers
- National Meteorological Centers

Dissemination and User Services

Table 2

TYPES OF COSTS *

Capital

- Equipment
- Installation
- Refurbishment

Operations

- Technicians-observers and operators
- Technicians--maintenance
- Meteorologists
- Parts and Supplies
- Expendables--balloons and radiosondes
- Other

Training

Technical Experts

* Costs may be local costs or foreign exchange costs.

Upper-air Station Observations

The most critical deficiency in the existing global observing network is the inadequacy of upper-air data in the tropics and the southern hemisphere. In general, there should be adequate data for global macroscale analyses and prognoses of surface and upper-air conditions and, insofar as possible, adequate data for research. Because of the difficulty of determining absolute requirements, it has been generally agreed by the W.M.O. that upper-air observations should have a minimum spacing over land and ocean areas of 600 n. mi.* It has also been agreed that wind, pressure-height, temperature, and moisture from the surface to at least the 10 mb. level should be measured at 00 and 12 GMT. (Stations taking all of these measurements are termed rawinsonde stations.)

There are presently about 450 rawinsonde stations that take observations at the required times. Recommendations for a minimum implementation program for upper-air stations for the 1968 to 1971 period have unofficially been made by the W.M.O. Secretariat as shown in Figure 1.** The networks in the developing countries can be expanded in three increments: (1) There are 32 existing rawinsonde stations which do not take observations at the required times and for which an expanded observational program has been recommended. (2) There are existing stations that either measure pressure-height, temperature and moisture or measure wind but not both. Adding the necessary equipment for both and expanding the observational program to include measurements at the required times has been recommended for 11 stations. (3) Entirely new

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*Ibid.

**W.M.O. Executive Committee XVIII Session, 1966, Document 44, Geneva, Switzerland.

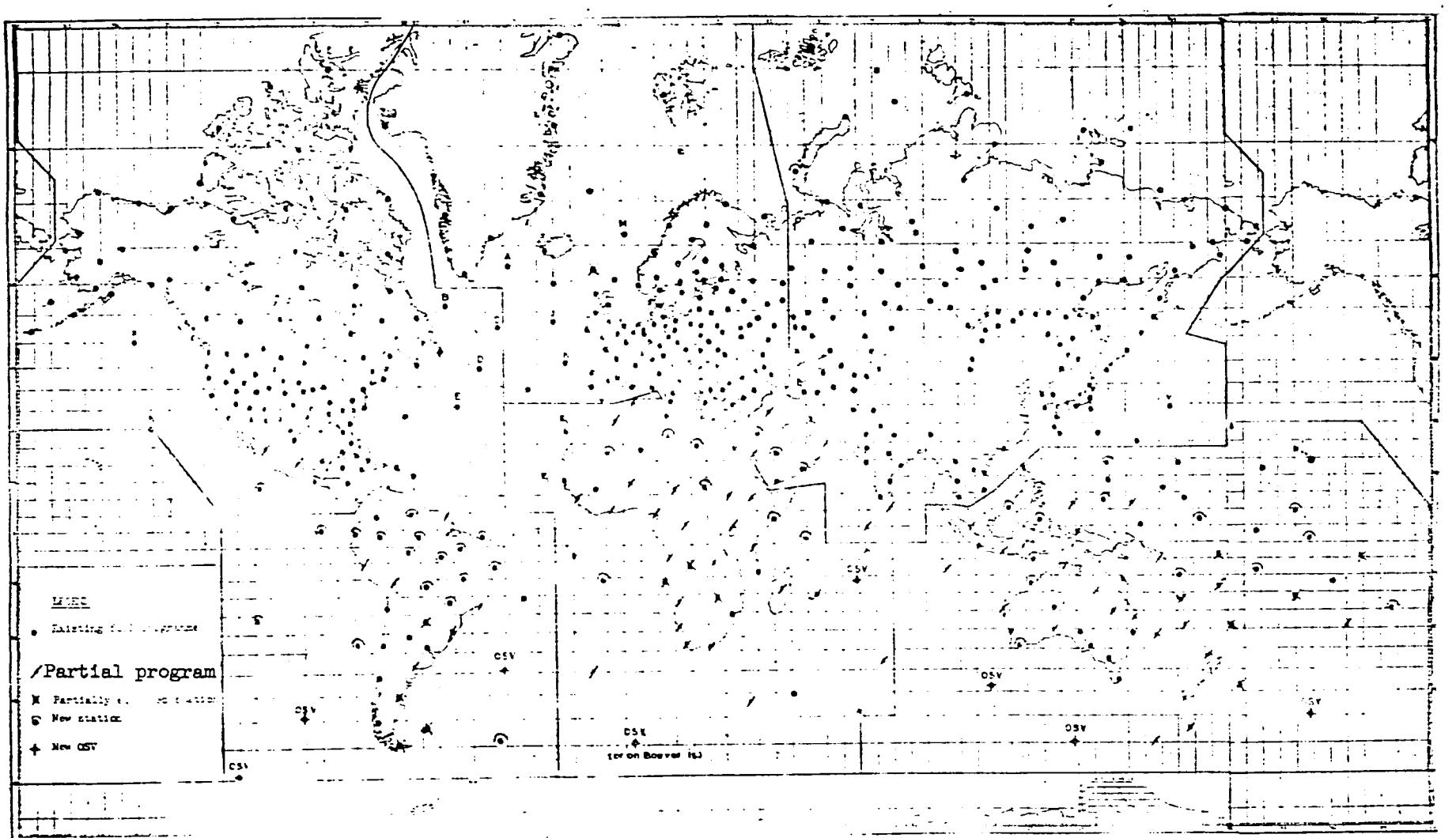

FIG. 1 RECOMMENDED UPPER-AIR STATION NETWORK

stations will be required to fill remaining gaps; 30 have been recommended. These figures include islands belonging to the less developed countries.

For an individual upper-air station, costs have been estimated as shown in Table 3. The number of upper-air stations and estimated costs are shown for the less developed countries in Table 4. Total estimated costs in the less developed countries for the three increments are summarized below:

Upper-air Stations Cost Estimates (Millions of U.S.$)

Capital costs		Annual Operational costs	
Equipment	1.8	Expendables	1.5
Installation	1.0	Other	1.0
Total	2.8	Total	2.5

Surface Station Observations

Many more surface stations will be required than upper-air stations; a guideline for minimum spacing has been suggested as 300 n. mi. over land areas or about four times the density of the upper-air network. Standard synoptic parameters would be measured four times daily. All upper-air stations are expected to carry on a surface observation program. The W.M.O. has noted that there are 260 surface stations which have not been established and 1,276 which are carrying on only a partial program.* However, the major problem would appear not to be augmentation but rather upgrading and refurbishing existing surface stations as necessary. It is very difficult to estimate the surface station deficiencies. For purposes of estimation, it is assumed that for every upper-air station in a less developed country,

*Ibid.

Table 3

Individual Upper-air Station Cost Estimates (U.S.$)

	First Increment (Augmented Observation Schedule)	Second Increment (Additional Equipment)	Third Increment (New Stations)
Capital Costs			
Equipment [a]	-	25,000	50,000
Installation [b]	-	10,000	30,000
Total		35,000	80,000
Annual Operational Costs			
Expendables [c]	15,000	15,000	30,000
Other [d]	5,000	8,000	22,000
Total	20,000	23,000	52,000

a.) Equipment: Standard surface instruments, rawinsonde, and hydrogen generator.

b.) Installation: Radome, shelter, and offices included.

c.) Expendables: Balloons and rawinsondes.

d.) Other: Personnel costs for operations and maintenance, spare parts, supplies, utilities, etc.

Table 4

Upper-Air Stations Costs by Region (Thousands of U.S. $)

	First Increment (Augmented Observation Schedule)		Second Increment (Additional Equipment)			Third Increment (New Stations)			Total	
	number	annual operation costs	number	capital costs	annual operation costs	number	capital costs	annual operation costs	capital costs	annual operation costs
Latin America	8	160	5	175	115	18	1,440	935	1,620	1,210
Africa	15	300	4	140	90	5	400	260	540	650
Asia	9	180	2	70	45	7	560	365	630	590
Total	32	640	11	385	250	30	2,400	1,560	2,790	2,450

except those already carrying on a full observation program, three surface stations require refurbishing. A major component of the planned USAID loan to Brazil in meteorology is for refurbishing existing surface meteorological stations; the cost has been estimated at $4,000 each. Based on this, total estimated costs in the less developed countries are:

Surface Station Cost Estimates (Thousands of U.S. $)

	Number	Meteorological Instruments	Installation and other improvements	Total
Latin America	93	280	90	370
Africa	72	220	70	290
Asia	54	160	60	220
Total	219	660	220	880

Regional Telecommunications Hubs

The success of the World Weather Watch will largely depend on the provision and efficient operation of meteorological telecommunications facilities. The design goal is for data from observing stations to be received at World Meteorological Centers (WMC's) within approximately one and one-half hours following observation, and for the transmission of WMC products to be completed within six to eight hours following observation. A high-speed trunk will be developed connecting the three WMC's at Melbourne, Moscow, and Washington with Regional Telecommunication Hubs (RTH's) in a number of regions. The trunk is planned as a high quality, low error rate network with a duplex 3 KC band-width capability. It is expected to be operated as a party line utilizing full-time cables and radio links, leased where possible. (See Figure 2.)

For implementation in the 1968 to 1971 period, the W.M.O. Secretariat has assumed that the communications system will be developed employing current proven technology (conventional wire, point-to-point radio, or general broadcast).* In this case, the use of existing networks, hubs and equipment with appropriate upgrading would be maximized. Where it is not possible to lease facilities, then high-frequency radio communications would have to be installed, especially for the meteorological communications. It should be

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*Fourth Report on the Advancement of Atmospheric Sciences and Their Application in the Light of Developments in Outer Space-August 1965, Secretariat of the W.M.O., Geneva, Switzerland.

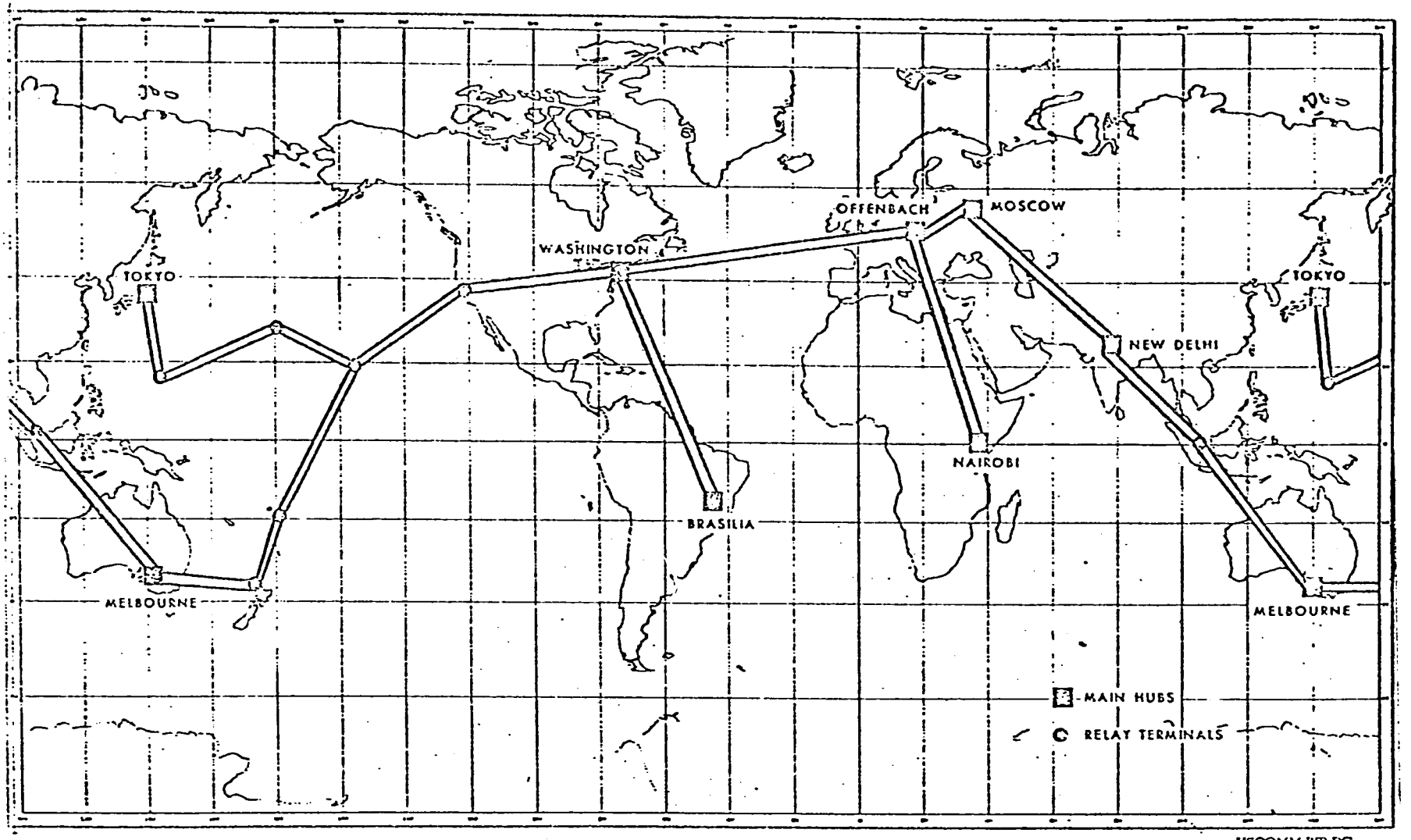

FIG. 2 PROPOSED TRUNK LINE

USCOMM-WB DC

recognized, however, that rapid advances in communications technology, in particular the utilization of satellites, are being made. The highly successful Early Bird satellite was launched in March, 1965, and today routinely carries about 20 percent of trans-Atlantic communications. As early as 1968 it is expected that several less developed countries will have ground terminals for communications using the next generation of satellites. Therefore, in the case of some less developed countries, it seems appropriate to await developments in satellite communications before making a firm decision on installing high-frequency radio transmission equipment. Satellite communications would be considerably more reliable than radio and would permit WMC's to link directly with a number of RTH's.

The World Weather Watch plan calls for three major RTH's in developing countries - Brasilia, Nairobi, and New Delhi. It does not appear that leased facilities will be available for linking these hubs with the global communications trunk, although satellite communications may become available. The capital costs for major RTH's are, therefore, estimated at $300,000 for high-frequency radio transmission equipment with voice, teletypewriter, and facsimile capabilities for the link with the global communications trunk and for regional broadcast facilities; $200,000 for a special purpose digital computer and associated peripheral equipment; and $250,000 for high-frequency radio transmission equipment with voice, teletypewriter, and facsimile capabilities for data collection and dissemination in the region. Annual operation costs are estimated at $50,000 for personnel (18 men), $30,000 parts, and $8,000 supplies.

In addition to the major RTH's, there will be some sub-regional centers or sub-RTH's. For purposes of estimation, it is assumed that there will be 2 in Latin America, 4 in Africa, and 3 in Asia. The capital costs for sub-RTH's are estimated at $250,000 including high-frequency radio communications equipment for the link with the RTH, for data collection and dissemination to other nations and the host nation, and for sub-regional broadcast facilities. Annual recurring costs are estimated at $16,000 for personnel (6 men), $9,000 parts, and $3,000 supplies.

These costs may be reduced somewhat by use of existing facilities. However, such facilities may require upgrading including extensive replacement of communications equipment. Personnel costs are estimated at about one-third those in the U.S. Parts costs include 5 percent of capital costs for equipment repairs and do not include amortization or depreciation costs.

Estimated capital and annual operational costs for RTH's and sub-RTH's are shown in Table 5.

National Meteorological Center Communications

Individual nations must be connected to RTH's. These connections should be point-to-point wire or radio links for timely data collection and dissemination; few such links now exist in the developing countries. A central collection point in a nation is assumed for convenience and called a National Meteorological Center (NMC). In those countries assumed to have major or sub-RTH's, the NMC communications function is accounted for. For purposes of estimation it is assumed that there are 6 additional NMC's in Latin America where it is desirable to have high-frequency radio transmission equipment with

Table 5

Regional Telecommunication Hub Cost Estimates [a]

	Capital Costs [b]	Annual Operational Costs [c]
Latin America		
Brasilia (RTH)	750	88
Buenos Aires (sub-RTH)	250	28
Maracay (sub-RTH	250	28
Total	1,250	144
Africa		
Nairobi (RTH)	750	88
Algiers (sub-RTH)	250	28
Cairo (sub-RTH)	250	28
Dakar (sub-RTH)	250	28
Kano (sub-RTH)	250	28
Total	1,750	200
Asia		
New Delhi (RTH)	750	88
Bangkok (sub-RTH)	250	28
Karachi (sub-RTH)	250	28
Manila (sub-RTH)	250	28
Total	1,500	172
Grand Total	4,500	516

a) The number and locations of sub-RTH's has not been decided.

b) Installation costs of 20 percent included.

c) Personnel costs are about half, and parts and supplies half.

voice, teletypewriter, and facsimile capabilities for connections to RTH's and voice transceivers for internal communications, 18 in Africa, and 18 in Asia. This would take care of all but some of the smaller countries for which single sideband transceivers could be used for communications with RTH's or other nations which would act as relay terminals. It is assumed that capital costs are $65,000 each (including installation of 20 percent) and annual operational costs are $10,000 each (personnel costs for 2 men are half, and parts and supplies half). Total estimated costs are:

NMC Communications Cost Estimates (Thousands of U.S.$)

	Number	Capital Costs	Annual Operational Costs
Latin America	6	390	60
Africa	18	1,170	180
Asia	18	1,170	180
Total		2,730	420

Internal Communications

Data must be collected from surface and upper-air stations in all nations. In most of the developing countries, communications are very poor and slow. If data is to be collected in a timely fashion, single sideband radios will have to be provided at observation stations in a large number of cases. For purposes of estimation, it is assumed that for every upper-air station in a less developed country, except those already carrying on a full observation program, an average of four observation stations need improved communications. Capital costs are estimated at $14,000 each including 20 percent for installation,

and annual operational costs at $2,000 for personnel and $700 for parts. Total estimated costs are:

Internal Communications Cost Estimates (Thousands of U.S.$)

	Number	Capital Costs	Annual Operational Costs
Latin America	124	1,740	330
Africa	96	1,340	260
Asia	72	1,010	190
Total		4,090	880

Regional Meteorological Centers

World Meteorological Centers at Washington, Moscow, and Melbourne will have major global data processing responsibilities. In addition, Regional Meteorological Centers (RMC's) will perform regional meteorological analysis and forecasting functions for the support of a group of national services. The roles, the number, and the locations of RMC's are still not fully determined. In many cases, these RMC's may be co-located with RTH's. For purposes of estimation, it is assumed that the following numbers will be required: 3 in South America, 5 in Africa, and 4 in Asia. Estimated capital costs are $250,000 each (or a total of $3.0 million) and annual operational costs of $50,000 each (or a total of $500,000).

National Meteorological Centers Analysis and Interpretation

While countries may be able to rely on RMC's to some extent for analysis and forecasting, each nation must have some capability for these functions.

Present capabilities in the less developed countries are generally limited, and it will be necessary in many countries to upgrade the analysis and interpretation capabilities so that productive and efficient use can be made of World Weather Watch products. Such upgrading is not a necessary part of the World Weather Watch in the sense that it does not affect the integrity of the global system. The principal needs are for more trained people and adequate professional opportunities and salaries for those who are trained. The major analysis center in a country is termed the National Meteorological Center (NMC) for convenience. (The NMC would also have communication functions.) Estimating costs for upgrading analysis and interpretation capabilities is very difficult and will depend on many factors, principally the present status and the improvements desired. For purposes of estimation, it is assumed that it is necessary to make improvements in 50 less developed countries at a cost each of $50,000 (or a total of $2.5 million) for capital equipment such as facsimile and APT and $10,000 (or a total of $500,000) for annual operational costs.

Dissemination and User Services

A major weakness of meteorological services in the less developed countries generally appears to be the minimal provision for dissemination of meteorological information to possible users including special services to users, such as frost warnings to farmers. Unless this situation is remedied, the benefits of meteorological facilities will be small. As for analysis and interpretation at NMC's, improvements in this area are not a necessary part of the World Weather Watch, and it is very difficult to estimate costs. For purpose of estimation

it is assumed that it is necessary to make improvements in 50 less developed countries at a cost each of $15,000 (or a total of $750,000) for annual operational costs.

Training

The estimated costs given in the previous sections did not include the education and training expenditures which will be associated with the operation of new and improved facilities which will be a part of the World Weather Watch. Estimated costs and the assumptions on which they are based are given in Table 6. The training of scientists and meteorologists may be primarily foreign exchange costs.

Technical Experts

Likewise, the estimated costs given in the previous sections did not include the costs of foreign technical experts (e.g., electronic technicians) which will be required to help with the implementation of World Weather Watch facilities in the less developed countries. This cost is estimated at about 20 percent of the total cost of equipment or $3.2 million (about 125 man-years).

In addition, it would be desirable to have a number of experts assist the less developed countries in improving the technical and administrative aspects of their meteorological services in general. For purposes of estimation, it is assumed that one technical assistant will be needed in 50 developing countries for an average of 2 man-years each. The estimated cost is $2.5 million.

Table 6

Estimated Training Costs (Thousands of U.S. $)

Type	Number	Cost	Explanation of Numbers
Scientist	50	500	1 each in 50 countries
Meteorologist	100	1,000	1 each in 100 forecast centers
Technician	450	2,000	3 each in 100 forecast centers 2 for each upper-air station
Rawinsonde Observers	200	600	4 for each new upper-air station 2 for each other upper-air station
Observers	450	450	2 for each refurbished surface station
Total	1,250	4,550	