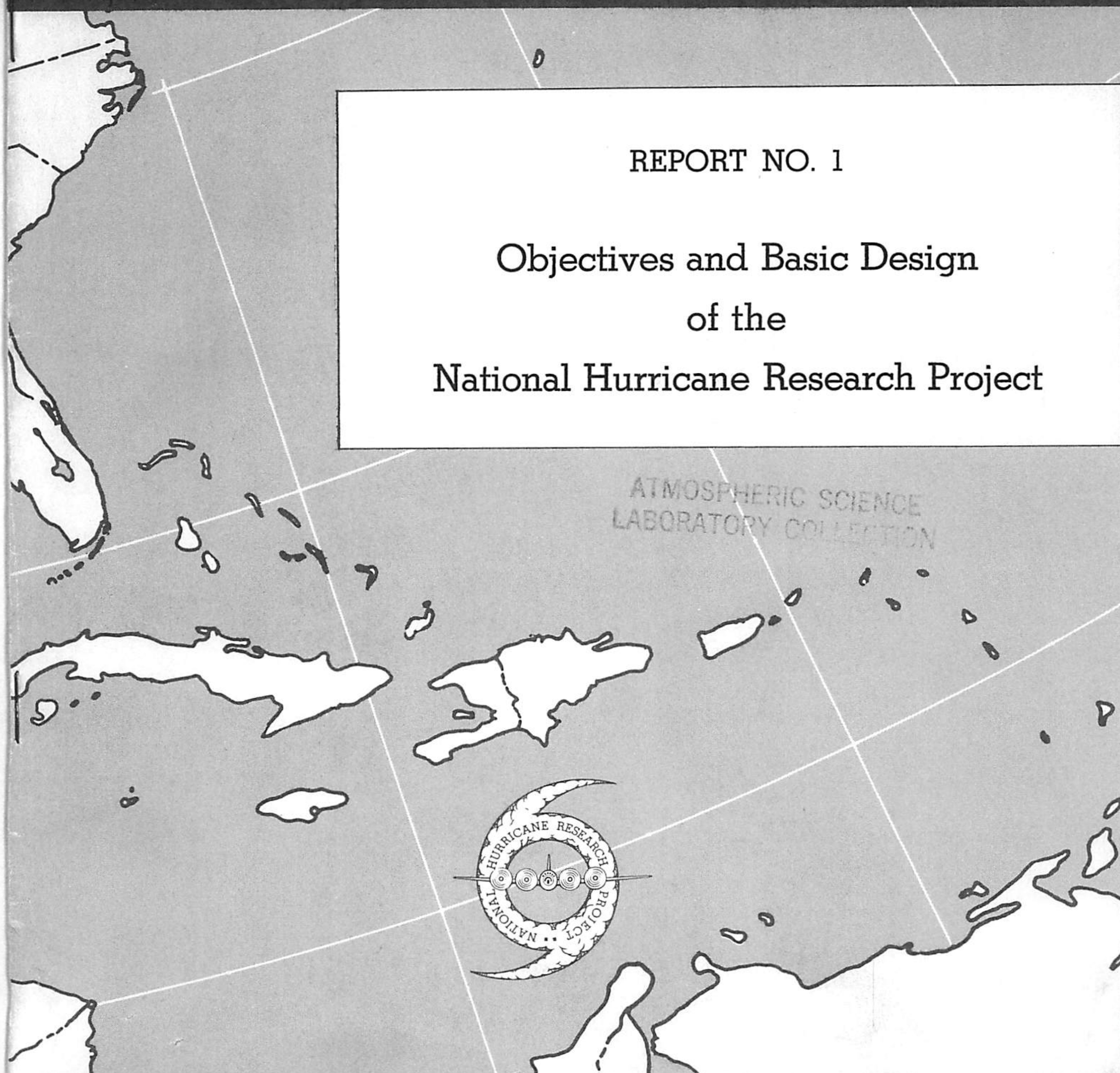
NATIONAL HURRICANE RESEARCH PROJECT



REPORT NO. 1

Objectives and Basic Design of the National Hurricane Research Project

U. S. DEPARTMENT OF COMMERCE
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Prepared by
Staff of the National Hurricane Research Project

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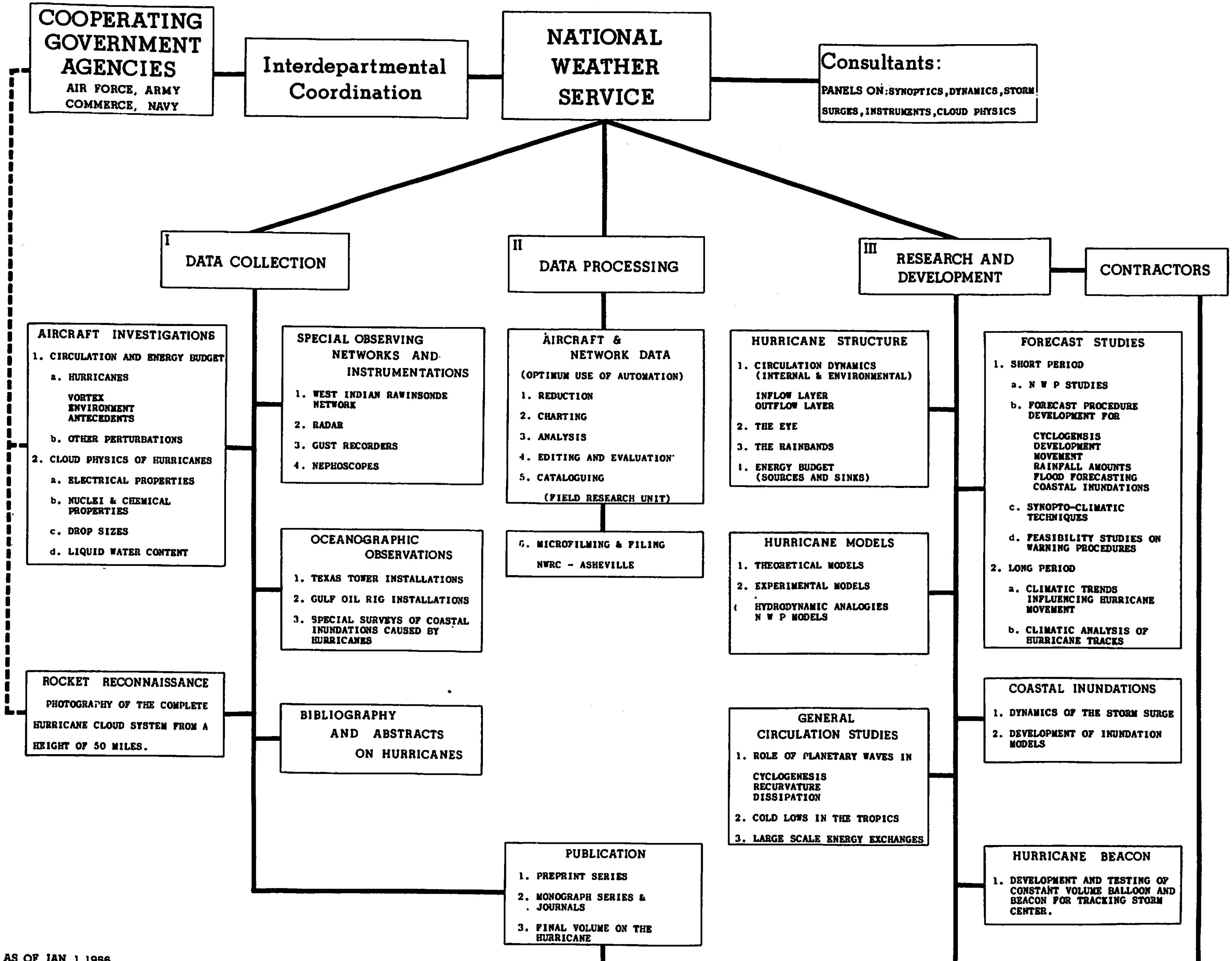

AS OF JAN. 1, 1956

Figure 1. National Hurricane Research Project, Task Organization Plan.

OBJECTIVES AND BASIC DESIGN OF THE NATIONAL HURRICANE RESEARCH PROJECT

Staff of the National Hurricane Research Project[1]
Washington, D. C.

The hurricane catastrophies of 1954 and 1955 provided the impetus for acceleration of research on the hurricane prediction problem. In the spring of 1955 Congress appropriated funds specifically for special investigations of severe storms including hurricanes. Planning for the Project actually began somewhat earlier at an interdepartmental conference held in Washington on December 17, 1954. Recommendations of this conference formed the basis for plans which have gradually taken the form outlined below. The program, under the sponsorship of the U. S. Weather Bureau, will include the cooperation or active participation of outstanding authorities on tropical meteorology from universities and other institutions as well as other government agencies. The general organization of the Project is outlined in figure 1. Some of the work was started as early as Fall 1955. The more intensive data collection program, beginning in May 1956, will continue for approximately 30 months. The research and development program is expected to require a minimum of four or five years.

The data collection and aircraft investigation programs will be designed to permit the testing of a number of working hypotheses concerning hurricane inception, movement, and development, but will be primarily for collection of information needed to accomplish the following objectives:

1. To investigate synoptic disturbances of the type that develop into hurricanes and to study the structure and behavior of these systems and their relation to large-scale flow features in an effort to discover the mechanisms of hurricane formation.

2. To examine the details of hurricane structure in order to understand the manner in which energy is released and transferred within the storm, and between the hurricane and its environment; and to determine the contribution to movement and changes of intensity respectively by the environment and by the internal mechanism of the storm.

3. To study the formation of clouds and rain in hurricanes and to investigate possible thermodynamic imbalances which may permit modification of the structure and movement of hurricanes.

4. To determine important parameters in hurricane forecasting and to investigate how these can best be observed by the reconnaissance aircraft and by other means.

To improve forecasts immediately as much as possible, a number of units have already begun to re-examine information at hand, seeking to develop more exact methods for predicting hurricane movement and for anticipating and describing its destructive potential. A portion of this work will be conducted under Public Law 71 (84th Congress, First Session) by the Hydrologic Services Division of the Weather Bureau, under transfer of funds from the U. S. Army Corps of Engineers. Applied research is being initiated at each of the hurricane forecast offices. In addition, the Office of Climatology and the Extended Forecast Section of the Weather Bureau will attempt to evaluate climatological trends and the degree to which they may influence the occurrence and tracks of hurricanes.

Research on the hurricane problem will be expanded as additional data are assembled. Some of the research will be undertaken at the Research Operations Base and by other divisions of the Weather Bureau. In addition, work vital to solution of the hurricane problem will be done by contractors at several universities.

REVIEW OF THE PROBLEM

A. INCEPTION. Tropical cyclones invariably form over oceanic regions where the water temperature is high and convective activity is pronounced. In this connection Palmén (1948) defined the threshold temperature of the ocean surface that is usually a prerequisite to hurricane formation. The high ocean surface temperatures

[1] Project personnel contributing to this paper include R. H. Simpson, Project Director; N. E. LaSeur, Associate Director; R. C. Gentry, Assistand Director; L. F. Hubert; and C. L. Jordan.

Figure 1. National Hurricane Research Project, Task Organization Plan.

are usually required for the air mass to be unstable. If temperatures in the upper troposphere are well below normal, the ocean temperatures may be slightly below the threshold figure given by Palmén, and the lapse rate in the air still be unstable. It is not surprising, therefore, that the early explanations of the inception of tropical cyclones emphasized convective processes. These hypotheses merely associated the convective activity and the cyclogenesis but offered no definite mechanism for organizing the disturbance or any means of predicting where it would form. These are serious limitations since convective processes are active over large areas during much of the year and since only a very small percentage of all rain-producing disturbances ever develop to tropical cyclone intensity. Among the mechanisms for concentrating and intensifying tropical disturbances, one of the first to be suggested was the Norwegian unstable frontal wave model in the Tropics, but this idea has been gradually abandoned as it became recognized that true fronts rarely, if ever, exist over the tropical oceans (Palmer 1952). Some of the more recent hypotheses emphasize the upper-level flow patterns (cf. Sawyer, 1947; Riehl, 1954). In part, these hypotheses call for an upper-level divergence field as a means of initiating low-level convergence and accounting for the pressure falls.

The structure of easterly waves and other types of tropical disturbances will be investigated in an attempt to delineate, in terms of forecast parameters, the basic differences between disturbances which develop into hurricanes and those which do not. It is important that we know why only a small portion of tropical perturbations develop into hurricanes. Thermodynamic aspects of this problem include sea-surface temperature, depth of the moist layer, and horizontal and vertical temperature and moisture gradients in the disturbance and in the air moving into the disturbance. An attempt will be made to isolate the significant dynamic factors by investigating the basic wind field and the associated fields of vorticity and momentum. This will include studies of the effect of advection of these quantities to and from the environment at all levels and interactions with neighboring disturbances.

B. STRUCTURE. One of the impressions which is common among those who have made many flights into hurricanes is that no two of the storms are quite alike. One of the more difficult tasks of the Project will be to distinguish structural features that are conservative from those that are transitory. Objectives in the investigation of structure are:

1. To establish the general features of the wind field and its variation with height and the variability of the wind over various space and time intervals.

2. To determine the geometry and dynamics of inflow and outflow layers and their variation with time.

3. To study the thermal structure of the hurricane as it relates to energy processes in the storm.

4. To study the structure and evolution of circulations in the eye.

5. To study the genetical source and development of the spiral rainbands and their relation to movement and intensification of the storm.

6. To derive an energy budget for the hurricane during several stages of development.

There will be several derived benefits if the above objectives are accomplished. When the structure of the hurricane is fully understood, we should be able to compute the effects of small changes in structure. This should add to the understanding of what makes a hurricane develop, move, and intensify or decay.

As a base line for designing the investigation of structure, the Project will draw upon the tentative model of hurricane circulations in figure 2 (Simpson, 1954) which has evolved from evaluations of earlier reconnaissance and rawinsonde data.

C. MOVEMENT. In a recent symposium on hurricanes at Florida State University, the point was made that meteorologists must now decide what they are attempting to track and forecast in dealing with the hurricane: the radar eye, the wind eye, the pressure center? As observational facilities increase, it becomes apparent that these features do not always coincide and that considerable error in tracking the storm may occur by plotting alternately the position of first one and then another of these centers. The Project expects to investigate these centers and attempt to determine which offers the most conservative means of tracking the progress of the storm.

The primary objective in studying hurricane movement will be to delineate insofar as possible the physical mechanism for movement of the storm. Various hypotheses and forecasting methods that have been advanced employ the concept of steering of hurricanes. The steering mechanisms include both thermal and kinematic properties, (cf. Riehl and Haggard, 1955; Gentry, 1951; and

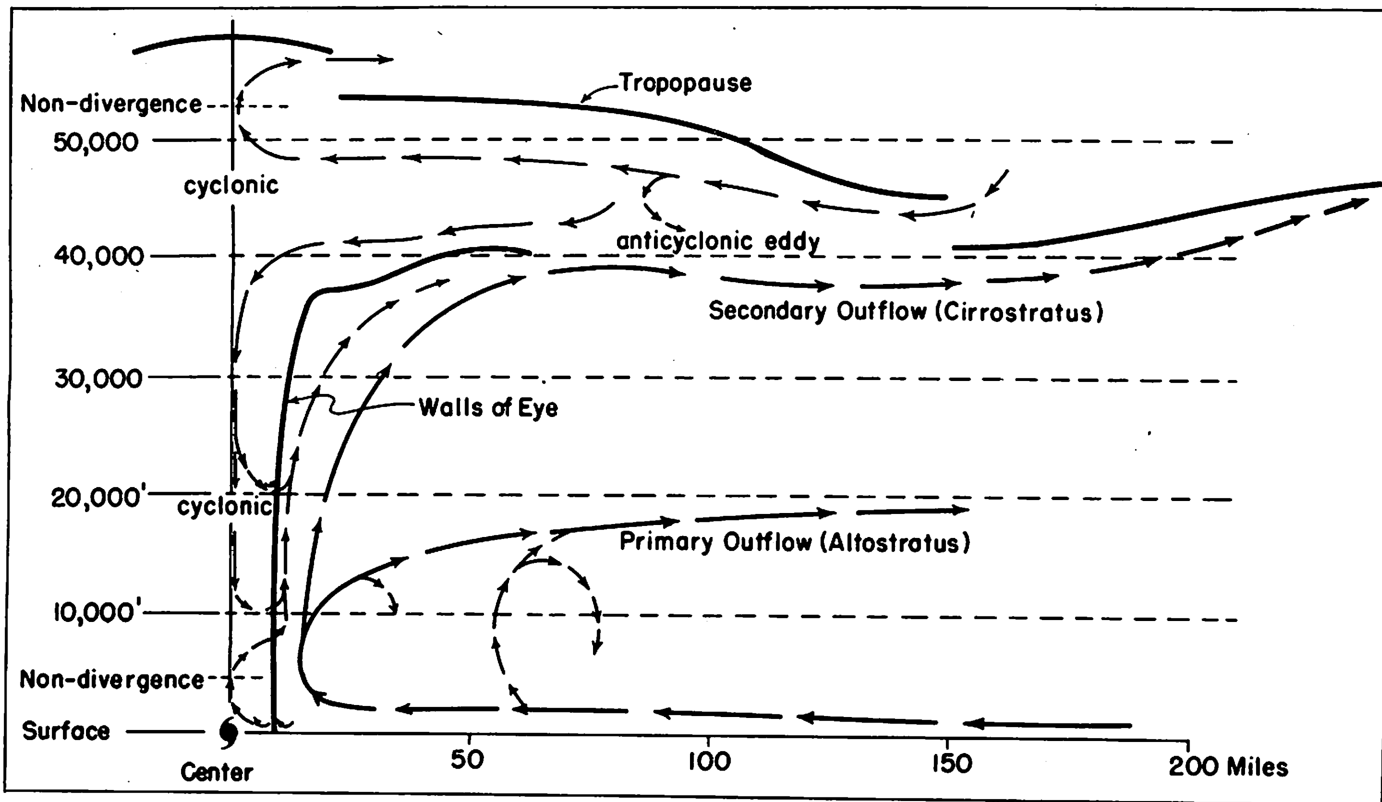

Figure 2. - Tentative model of hurricane circulation (Simpson, 1954).

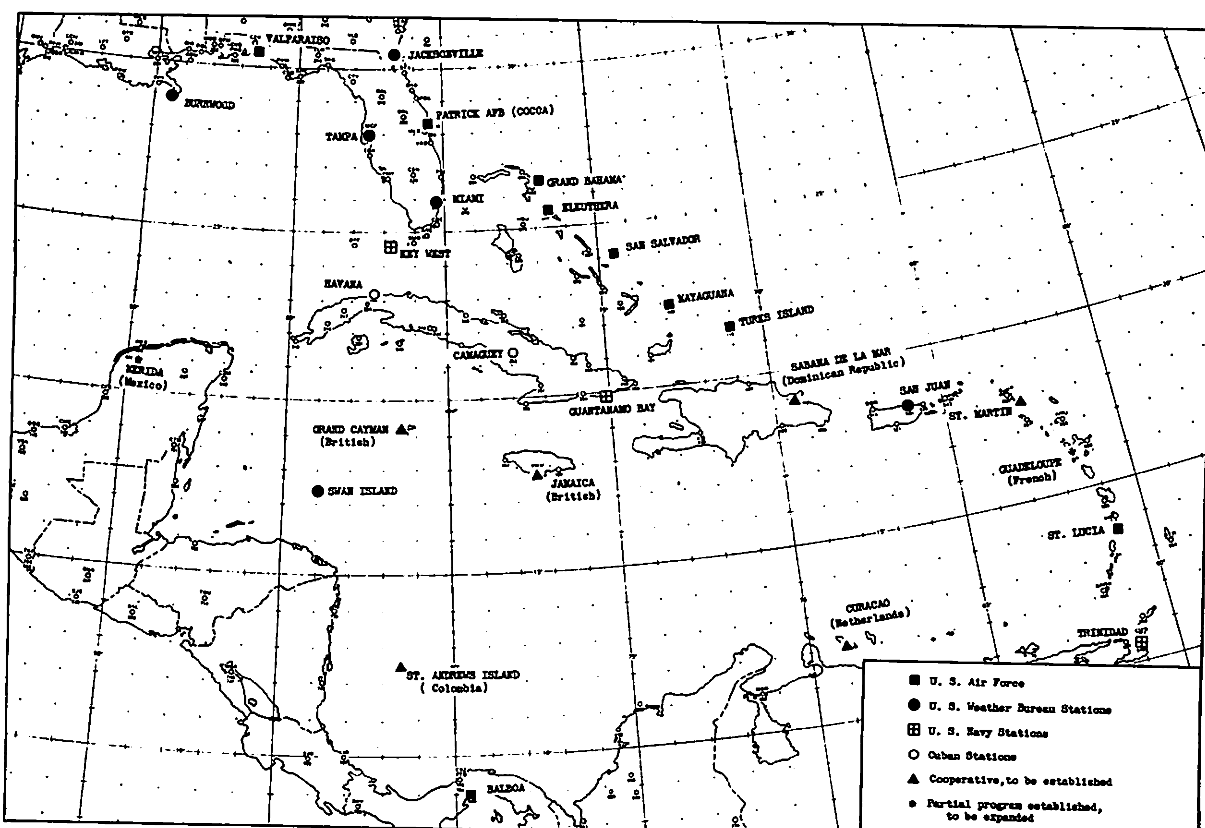

Figure 3. - Network of rawinsonde stations which will begin operation 1 May 1956.

Simpson, 1946). Most of the forecasting methods assume that a hurricane is steered essentially by its environmental circulations, except for contributions from internal forces as described by Yeh (1950), Rossby (1948), Cressman (1952), and Gentry (1952). Actually a major hurricane drains from its environment several billion tons of air per minute at low levels and returns that mass to its surroundings in the upper atmosphere. The internal dynamics of the storm itself cannot be assumed a priori to play an insignificant role in the overall physics of movement. It will be the objective of the Project to determine the individual contribution to storm movement by the environmental circulations by interaction forces, and by purely internal forces.

It is reasonable that the internal dynamics of the hurricane should contribute to the movement of hurricane for several reasons. Low-level wind data and radar observations of hurricanes indicate that locations of areas of maximum mass convergence in the lower levels vary considerably with respect to the hurricane center. Similar variations of the areas of mass divergence in the upper levels of the storm would also be expected. Although the locations of these convergent and divergent areas are partially determined by the vorticity of the air entering the hurricane circulation, they may also be influenced by the internal dynamics of the hurricane, the amount of moisture in the ambient air, the latent heat released in the hurricane, and other factors. When mass divergence at high levels is not balanced by equal mass convergence at low levels, the pressure at the surface near the hurricane changes and the storm moves and/or changes intensity. If the upper divergent and lower convergent areas shift with respect to each other and with respect to the center of the hurricane, the direction and/or speed of movement of the hurricane should also change. Since there is such intense convective activity in a hurricane, changes in the low-level convergent areas should affect the locations of the higher level divergent areas and vice versa. The extent of this internal influence may depend not only on the intensity of the convective activity, but also on the amount of latent heat released and the location of maximum release.

If a means is ever to be found for modifying or diverting the movement of the hurricane, it will likely depend upon a modification of the force fields within the storm itself, possibly through some means of shifting or intensifying the release of latent heat of fusion in one storm sector. Most of the energy of a hurricane arises from the release of latent heat. While precipitation may be initiated in natural clouds by either the sublimation-coalescence or condensation-coalescence mechanisms and the net gain to the atmosphere of energy is approximately the same for the two mechanisms, the energy distribution in the storm and energy redistribution to the environment of the storm may be markedly different in the two cases. Based on our present knowledge of the physics of clouds and rain formation, the shifting or intensifying of the release of latent heat of fusion in a sector would require the existence in the hurricane of large amounts of supercooled water drops. It would also probably depend on locating potentially unstable situations, since small changes in stable situations will be rapidly compensated. The possibility, however, that the formation or the movement of a hurricane can at critical times rest upon a very delicate balance of forces offers an intriguing challenge.

D. CHANGES OF INTENSITY (DEVELOPMENT). Investigations will be undertaken to evaluate the importance of friction, moisture variations, and changes in temperature gradient surrounding the storm vortex upon intensification and decay of hurricanes.

E. STORM SURGE. The greatest loss of life in hurricanes usually comes from inundation as the storm crosses the coastline and cascades large quantities of sea water upon land. In spite of this, many storms apparently cross the coastline without producing important flooding or damage from sea water. It will be a primary objective to study oceanographic and hydrographic conditions in relation to the hurricane itself in an effort to determine the conditions which are both necessary and sufficient for producing important inundations.

F. FLOODS. Except for the storm surge, floods caused by rains associated with hurricanes cause more loss of life and greater property damage than anything else connected with hurricanes. Hurricane Diane was the first "billion dollar hurricane" and largely because of the floods that devastated valleys from eastern Pennsylvania to eastern Connecticut. Investigations of the flood-producing potential of hurricanes, already underway, will be intensified.

DATA COLLECTION

The collection of additional data required for research on the hurricane problem will make use of a dense network of rawinsonde stations in the West Indies, specially equipped aircraft for research flights into hurricanes and other synoptic disturbances in the Tropics, and rocket reconnaissance of hurricane cloud systems.

Figure 3 shows the proposed network of rawinsonde stations which will operate continuously for a

30-month period beginning 1 May 1956. The network includes 8 stations to be operated by the U. S. Air Force, 3 by the U. S. Navy, 2 by the British, 2 by the French, 2 by Cuba, and 1 each by the Dutch, Dominican Republic, Mexico, and Colombia.

At each of these stations two soundings per day will be made using instruments and methods of operation which will insure optimum compatibility of observations. Specially trained technicians at each station will attempt to obtain upper-air soundings consistently above 80,000 ft.

To supplement the rawinsonde network and obtain details of the structure of hurricanes in various stages of development, specially instrumented aircraft will be operated routinely in the West Indies area. These aircraft assigned to the Project by the Department of Defense and operated by the Air Weather Service include one B-47 and two B-50's. Flights will probably be made several times per week by two or three planes flying at elevations ranging from near the surface to above 40,000 ft. During hurricanes every attempt will be made to put three aircraft into the storm area simultaneously, one collecting data first at approximately 1,000 ft., then later at 8,000 ft; the second aircraft, flying first at 15,000 ft. will later climb to 25,000 ft.; the third aircraft entering the storm at 30,000 to 35,000 ft. will eventually climb to above 40,000 ft. Each of the aircraft will be instrumented with the most advanced meteorological equipment, including vortex-, aspirator-, and stagnation-temperature probes, infra-red absorption hygrometers, sea-surface temperature radiometers (for low-level flights), accurate D-value computers, automatic wind measuring equipment, and considerable supplemental equipment for cloud physics studies. The latter will include instruments for measuring drop sizes and distributions, liquid water content, electric field strength, and both condensation and freezing nuclei distributions. All meteorological and some navigational data will be recorded in digital form and/or on a photopanel. The more important meteorological elements will be recorded digitally and in such form as to permit great speed in data reduction and plotting. Automatic processing equipment will enable Project scientists to complete within 24 hours after the planes return the preliminary analysis of these elements, thus permitting adjustments and revisions of plans before the next research reconnaissance flight is made.

A number of rocket launchings will be made under the direction of the Office of Naval Research in an attempt to photograph, from altitudes above 50 miles, the entire hurricane cloud system and its immediate environment. This, if successful, will permit an assessment of the overall size and influence of the storm on hydrometeors of the region during the time that aircraft are sweeping out details of the fine structure of the hurricane.

The Project expects also to obtain from the U. S. Navy's transosonde flights valuable observations at the 200-mb. level in the tropical areas.

RESEARCH OPERATIONS BASE

A Research Operations Base will be set up in Florida for the purpose of directing the data collection program, analyzing the results, and conducting at least the first phases of research with the aid of these data. As a part of the R.O.B. program, an experimental tropical analysis unit will be operated in which daily analyses and experimental prognoses will be made for the West Indian test area. One objective of this center will be to develop more useful tools of analysis and modes of presentation for tropical regions. This unit will study energy sources and energy transport in the Tropics, and determine the best means of detecting and representing these through synoptic analyses compatible with network limitations in such areas.

RESEARCH AND DEVELOPMENT

While limited forecast development studies will be pursued at all hurricane forecast centers of the Weather Bureau, a more intense study of the forecast problem will be undertaken at the Miami hurricane center which will have more opportunity for direct collaboration with the work at the Research Operations Base than other forecast offices.

Elsewhere in the Weather Bureau and among Weather Bureau contractors, research has already started on the storm surge problem, and on preparing dynamical and numerical prediction models of hurricanes.

Eleven research tasks have been assigned to the Research Operations Base. These research studies will be in addition to the ones outlined previously that are being conducted by other divisions in the Weather Bureau on climatological trends, storm surge, and the work being done by the Hydrologic Services Division under transfer of funds from the U. S. Army Corps of Engineers. The meteorologists at the Research Operations Base will be divided into teams to work on the following phases of the hurricane problem:

1. Hurricane circulation and structure.

2. Energy processes and hurricane energy budget.

3. Momentum transfer within the hurricane and between the hurricane and its environment.

4. Dynamics of hurricane movement.

5. Conditions antecedent to hurricane formation.

6. Analysis of errors in observations made in the Tropics.

7. Large scale energy transport in the Tropics and from the Tropics to other areas.

8. Cloud physics of hurricane clouds and precipitation.

9. Artificial modification of hurricane structure and movement.

10. Forecast applications of findings of the National Hurricane Research Project.

11. The hurricane beacon, a radio balloon designed to float at constant pressure in the eye and signal its position as an aid in studying circulations in the eye, and possibly in tracking the movement of the storm center.

PUBLICATION OF RESULTS

It is tentatively planned to issue progress reports and results of special studies growing out of the Hurricane Project as promptly as possible. The more important papers and investigation results will be offered for publication in scientific journals and monograph series which insure very wide circulation.

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